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(54) **Title:** TRANSFER CASE ACTIVE CLUTCH ACTUATION MECHANISM HAVING ACTUATOR LEVERS WITH COLD FORMED FEATURES

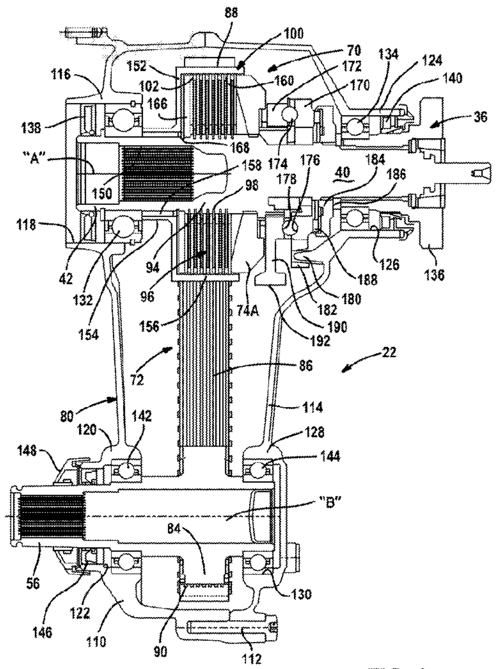


FIG. 3

(57) **Abstract:** A ballramp unit for use in a power-operated clutch actuator for generating and applying a clutch engagement force to a multi-plate friction clutch. The ballramp unit includes first and second cam rings. At least one of the first and second cam rings are hot forged with localized visual indicators that designate localized locations to receive a cold forming operation. The localized visual indicator can include one of a depression and a projection. The cold forming operation is carried out on the localized location to provide desired structural or physical features. The cold forming operation can include cold forming corresponding ball ramp pockets on a pair of cam rings and may further include cold forming at least one locator tab.

WO 2019/135984 A1

TRANSFER CASE ACTIVE CLUTCH ACTUATION MECHANISM HAVING ACTUATOR LEVERS WITH COLD FORMED FEATURES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 62/614,057 filed on January 5, 2018, the entire disclosure of which is hereby incorporated by reference.

FIELD

[0002] The present disclosure relates generally to power transfer systems for controlling the distribution of drive torque from a powertrain to front and rear drivelines of a four-wheel drive (4WD) or an all-wheel drive (AWD) motor vehicle. More specifically, the present disclosure is directed to a clutch actuation mechanism of the type used in power transfer assemblies, such as transfer cases and power take-off units, to actively control a multi-plate clutch assembly.

BACKGROUND

[0003] This section provides background information which is not necessarily prior art to the inventive concepts associated with the present disclosure.

[0004] Interest in four-wheel drive (4WD) and all-wheel drive (AWD) vehicles has led to development of power transfer systems configured to selectively and/or automatically direct rotary power (i.e. drive torque) from the powertrain to all four wheels of the vehicle. In many 4WD vehicles, the power transfer system includes a transfer case configured to selectively transmit drive torque from the powertrain to the front driveline. In AWD vehicles, the power transfer system includes a power take-off unit (commonly referred to as a “PTU”) configured to selectively transmit drive torque from the powertrain to the rear driveline.

[0005] Many current transfer cases are configured to include a rear output shaft interconnecting the powertrain to the rear driveline, a front output shaft interconnected to the front driveline, a transfer assembly drivingly interconnected to the front output shaft, a mode clutch for selectively coupling the transfer assembly to the rear output shaft, and a clutch actuator for controlling actuation of the mode clutch. The mode clutch is operable in a first or “released” state to disconnect the front output shaft from the rear output shaft and establish a two-wheel drive mode (2WD) with all drive torque transmitted from the powertrain to the rear driveline. The mode clutch is also operable in a second or “engaged” state to drivingly connect the front output shaft (via the transfer assembly) to the rear output shaft and establish a four-wheel drive mode (4WD) with drive torque transmitted from the powertrain to both of the front and rear drivelines.

[0006] Some “part-time” transfer cases are equipped with a positive-locking type of mode clutch, such as a dog clutch, which can be selectively actuated to shift between the two-wheel drive mode (2WD) and a locked four-wheel drive mode (LOCK-4WD). As an alternative, “active” transfer cases are equipped with an on-demand mode clutch, such as an adaptively-controlled multi-plate friction clutch, configured to automatically control the drive torque distribution between the front and rear drivelines without any input or action on the part of the vehicle operator so as to provide an on-demand four-wheel drive mode (AUTO-4WD) in addition to the two-wheel drive mode (2WD). Typically, active transfer cases include a power-operated clutch actuator that is interactively associated with an electronic traction control system having a plurality of vehicle sensors. The power-operated clutch actuator regulates the magnitude of a clutch engagement force applied to the multi-plate friction clutch based on vehicular and/or road conditions detected by the sensors, thereby adaptively regulating the drive torque distribution ratio between the front and rear drivelines.

[0007] The power-operated clutch actuator installed in many modern transfer cases includes a moveable actuation component adapted to exert the compressive clutch engagement force on the multi-plate friction clutch, a force generating mechanism operable to generate and apply the clutch engagement force to the moveable actuation component, and a powered drive unit controlling actuation of the force generating mechanism. The moveable actuation component is typically configured as a pressure plate while the force generating mechanism is commonly configured as a ballramp unit. The ballramp unit includes a pair of cam rings each having a plurality of ballramp grooves, and a plurality of rollers with each roller being disposed in an aligned set of the ballramp grooves such that relative rotation between the cam rings results in axial movement of the pressure plate. The powered drive unit controls the direction and amount of relative rotation between the cam rings so as to control the position of the pressure plate relative to the multi-plate friction clutch, thereby controlling the magnitude of the clutch engagement force.

[0008] Currently, the cam rings are forged components that require extensive machining. Unfortunately, machining of the forged cam rings requires large capital investments in machinery and perishable tooling, in addition to significant manpower requirements. While conventionally-fabricated cam rings are well-recognized to be part of a preferred clutch actuation mechanism, a need exists to develop alternative fabrication methods for cam rings which overcome some of the above-noted shortcomings associated with conventional machining requirements.

SUMMARY

[0009] This section provides a general summary of some of the inventive concepts associated with the present disclosure and is not intended to be interpreted as a complete and exhaustive listing of all of its aspects, objectives and embodiments.

[0010] It is one aspect of the present disclosure to provide a motor vehicle having a powertrain normally transmitting drive torque from a powertrain to a primary driveline. A power transfer assembly is further provided and is operable to selectively transmit drive torque to a secondary driveline. The power transfer assembly comprises a friction clutch assembly having a first clutch member receiving drive torque from the powertrain, a second clutch member drivingly interconnected to the secondary driveline, and a multi-plate clutch pack operably disposed between the first and second clutch members. A power-operated clutch actuator includes an actuation component moveable relative to the clutch pack and a force generating mechanism operable to generate and cause the actuation component to apply a clutch engagement force on the clutch pack. The power transfer assembly further includes a powered drive unit for controlling actuation of the force generating mechanism, wherein the force generating mechanism includes a ballramp unit having first and second cam rings at least one of which is cold formed to define a structural feature.

[0011] It is a related aspect of the present disclosure to provide a method of assembling at least one cam ring in a clutch actuator, the clutch actuator adapted to control compressive clutch engagement force on a multi-plate clutch pack in order to regulate drive torque from a primary driveline to a secondary driveline. The method includes hot forging at least one cam ring having a ring portion and a lever extension. The hot forging process includes forming at least one localized visual indicator on the ring portion and/or the lever extension that designates a localized location to receive a cold forming operation. Using the localized visual indicators as a reference, features are cold formed into the localized locations

[0012] It is a further related aspect of the present disclosure to provide additional cold formed structural features on the cam rings including at least one of ballramp grooves, locating tabs, flats, lengths, OD pilots, roller bosses and/or locating bosses.

[0013] In accordance with these and other aspects, the present disclosure is directed to a power transfer assembly for installation in a motor vehicle and which is operable to normally transmit drive torque from a powertrain to a primary driveline and to selectively transmit drive torque to a secondary driveline through an actively-controlled multi-plate friction clutch. The power transfer assembly further includes a power-operated clutch actuator having an actuation component moveable relative to the multi-plate friction clutch, a force generating mechanism operable to generate and apply a clutch engagement force to the moveable actuation component, and a powered drive unit controlling actuation of the force generating mechanism. The force generating mechanism includes a ballramp unit having first and second cam rings, and a plurality of rollers each being retained in one of a common plurality of aligned sets of ballramp grooves formed in the first and second cam rings. The ballramp grooves are formed using a cold forming process instead of a machining process to provide an advantageous result in terms of reduced manpower, tooling and equipment.

[0014] The present disclosure is further directed to cold forming other structural features on the can rings which can include locator tabs, flats, pilot segments, boss segments, apertures, undercuts and/or weight reduction holes.

[0015] Further areas of applicability will become apparent from the description provided herein. As noted, the description and specific embodiments disclosed in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0016] The drawings described herein are only for purposes of illustrating selected embodiments and not all implementations or variations thereof. As such, the drawings are not intended to limit the scope of the inventive concepts associated with the present disclosure. In the drawings:

[0017] FIG. 1 is a schematic illustration of a four-wheel drive motor vehicle configured to be equipped with a power transfer assembly, such as a transfer case, having a ballramp type of force generating mechanism with cam rings constructed in accordance with the teachings of the present disclosure;

[0018] FIG. 2 is a diagrammatical illustration of a transfer case configured for installation in the motor vehicle shown in FIG. 1;

[0019] FIG. 3 is a sectional view of a transfer case constructed in accordance with a first non-limiting embodiment;

[0020] FIG. 4 is an enlarged partial view of the multi-plate friction clutch and the power-operated clutch actuator associated with the transfer case shown in FIG. 3;

[0021] FIG. 5 is a sectional view showing a power-operated clutch actuator for actuating the multi-plate friction clutch associated with the transfer case shown in FIGS. 3 and 4;

[0022] FIG. 6 is a partial sectional view of a transfer case constructed in accordance with a second non-limiting embodiment;

[0023] FIG. 7 illustrates a modified version of the transfer case shown in FIG. 6 and provides additional details of the power-operated clutch actuator;

[0024] FIGS. 8A and 8B are isometric views of first and second cam rings associated with a power-operated clutch actuator similar to that shown in FIG. 7;

[0025] FIGS. 9A and 9B illustrate cold formed structural features associated with the first cam ring shown in FIG. 8A;

[0026] FIGS. 10A and 10B illustrate cold formed structural features associated with the second cam ring shown in FIG. 8B;

[0027] FIG. 11A is a process flowchart for manufacturing first cam rings using conventional machining operations while FIGS. 11B and 11C are alternative process flowcharts for manufacturing first cam rings using cold forming operations in accordance with the teachings of the present disclosure;

[0028] FIG. 12A is a process flowchart for manufacturing second cam rings using conventional machining operations while FIGS. 12B and 12C are alternative process flowcharts for manufacturing second cam rings using cold forming operations in accordance with the teachings of the present disclosure;

[0029] FIGS. 13A and 13B illustrate modified versions of the first and second cam rings shown in FIGS. 8A and 8B; and

[0030] FIGS. 14A-14C illustrate alternative modified versions of the first and second cam rings.

[0031] Corresponding reference numerals are used throughout the various views provided in the above-noted drawings to identify common components.

DETAILED DESCRIPTION

[0032] Example embodiments of a power transfer assembly for use in motor vehicles having a multi-plate friction clutch and power-operated clutch actuator will now be described. Specifically, the power-operated clutch actuator associated with each power transfer assembly includes a ballramp unit having cam rings fabricated using cold forming processes in accordance with inventive concepts of the present disclosure. However, these specific example embodiments are provided so that this disclosure will be thorough and will fully convey the intended scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known device structures and well-known technologies are not described in detail.

[0033] Referring initially to FIG. 1 of the drawings, an example of a four-wheel drive motor vehicle 10 is shown to generally include a longitudinally-extending (i.e. north/south configuration) powertrain 12 operable for generating rotary power (i.e. drive torque) to be transmitted to a primary driveline 14 and a secondary driveline 16. Powertrain 12 is shown to include an internal combustion engine 18, a multi-speed transmission 20, and a power transfer assembly hereinafter referred to as transfer case 22. In the particular arrangement shown, primary driveline 14 is the rear driveline and secondary driveline 16 is the front driveline so as to establish a four-wheel drive (4WD) arrangement. It is contemplated that an all-wheel drive (AWD) arrangement can be configured in the alternative with front driveline 16 acting as the primary driveline and rear driveline 14 acting as the secondary driveline. In such an arrangement, the power transfer assembly would be configured as a power take-off unit.

[0034] Rear driveline 14 is configured to include a pair of ground-engaging rear wheels 24 drivingly connected via corresponding rear axleshafts 26 to a rear differential assembly 28 associated with a rear axle assembly 30. Rear driveline 14 also includes a rear propshaft 32 arranged to interconnect a rotary input 34 of rear differential assembly 28 to a rear output shaft 36 of transfer case 22. A pair of rear joint units 38 are shown to interconnect opposite ends of rear propshaft 32 to rotary input 34 of rear differential assembly 28 and rear output shaft 36 of transfer case 22 and which function to transmit drive torque while permitting angular and/or translational movement therebetween.

[0035] Front driveline 16 is configured to include a pair of front ground-engaging wheels 44 drivingly interconnected via corresponding front axleshafts 46 to a front differential assembly 48 associated with a front axle assembly 50. Front driveline 16 also includes a front propshaft 52 arranged to interconnect a rotary input 54 of front differential assembly 48 to a front output shaft 56 of transfer case 22. A pair of front joint units 58 interconnect opposite ends of front propshaft 52 to rotary input 54 of front differential assembly 48 and front output shaft 56 of transfer case 22 and function to transmit drive torque while permitting angular and/or translational movement therebetween. A disconnect coupling 60 is also associated with front driveline 16 and is shown operably disposed between a pair of shaft segments 46A, 46B of one of front axleshafts 46. Disconnect coupling 60 is operable in a first or “connected” mode to drivingly couple front wheels 44 to the remainder of front driveline 16 and is further operable in a second or “disconnected” mode to uncouple front wheels 44 from driven connection with the reminder of front driveline 16.

[0036] Powertrain 12 is also shown in FIG. 1 to be operably associated with a powertrain control system 62 generally including a group of vehicle sensors 64 and a mode selector 66, both of which provide signals which communicate with a vehicle controller 68. Vehicle controller 68 can include one or more individual controllers associated with engine 18, transmission 20, transfer case 22 and disconnect coupling 60 which are configured to control motive operation of vehicle 10. Powertrain control system 62 is shown to provide an electronically-controlled power transfer system configured to permit a vehicle operator to select between a two-wheel drive (2WD) mode, a part-time or "locked" four-wheel drive (LOCK-4WD) mode, and an adaptive or "on-demand" four-wheel drive (AUTO-4WD) mode. In this regard, transfer case 22 is equipped with a mode clutch 70 and a transfer assembly 72 configured to transfer drive torque to front driveline 16 when one of the four-wheel drive modes is selected. As will be detailed hereafter with greater specificity, mode clutch 70 functions to selectively transmit drive torque from rear output shaft 36 to front output shaft 56 via transfer assembly 72.

[0037] The power transfer system is shown to also include a power-operated clutch actuator 74 for controlling actuation of mode clutch 70, and a power-operated disconnect actuator 76 for controlling actuation of disconnect coupling 60. Controller 68 controls coordinated actuation of power-operated actuators 74, 76 in response to input signals from vehicle sensors 64 and mode signals from mode select mechanism 66. Vehicle sensors 64 are arranged and configured to detect certain dynamic and operational characteristics of vehicle 10 and/or current weather or road conditions.

[0038] To establish the 2WD mode, clutch actuator 74 is controlled to shift mode clutch 70 into a first or "released" mode while disconnect actuator 76 is controlled to shift disconnect coupling 60 into its disconnected mode. With mode clutch 70 in its released mode, drive torque is not transmitted through transfer assembly 72 to front output shaft 56 such that virtually all drive torque generated by powertrain 12 is delivered to rear wheels 24 via rear driveline 14.

[0039] To establish the LOCK-4WD mode, disconnect actuator 76 is controlled to shift disconnect coupling 60 into its connected mode and clutch actuator 74 is controlled to shift mode clutch 70 into a second or “fully-engaged” mode. With mode clutch 70 operating in its fully-engaged mode, rear output shaft 36 is, in effect, directly coupled to front output shaft 56 via transfer assembly 72 such that drive torque is equally distributed (i.e. 50/50) therebetween. With disconnect coupling 60 in its connected mode, shaft segments 46A, 46B are drivingly coupled together such that drive torque delivered to front output shaft 56 is transferred via front driveline 16 to front wheels 44.

[0040] To establish the AUTO-4WD mode, disconnect coupling 60 is shifted into, or maintained in, its connected mode and clutch actuator 74 operates to adaptively regulate the drive torque distribution between rear output shaft 36 and front output shaft 56 by varying operation of mode clutch 70 between its released and fully-engaged modes. The torque distribution ratio is based on and determined by control logic associated with controller 68 which is configured to determine a desired or “target” amount of the total drive torque to be transmitted to front output shaft 56 based on the operating characteristics and/or road conditions detected by sensors 64.

[0041] Referring now to FIG. 2 of the drawings, an example embodiment of transfer case 22 will now be described in detail. Transfer case 22 generally includes a t-case housing 80, rear output shaft 36, front output shaft 56, transfer assembly 72, mode clutch 70, and power-operated clutch actuator 74. In this non-limiting example, a component of transfer assembly 72 is combined with a component of mode clutch 70 to define an “integrated torque transfer” component which facilitates a compact "stacking" arrangement between mode clutch 70 and transfer assembly 72. This stacked arrangement results in a reduced axial packaging of transfer case 22 in comparison to "unstacked" arrangements in known transfer cases. In the particular example disclosed, the integrated torque transfer component combines a first transfer member or first sprocket 82 of transfer assembly 72 with a first clutch member or clutch drum 92 of mode clutch 70, hereinafter the combined component being cumulatively referred to as a sprocket drum 100. Sprocket drum 100 is rotatably supported on rear output shaft 36.

[0042] In addition to first sprocket 82, transfer assembly 72 also includes a second transfer member or second sprocket 84 that is fixed to, or formed integrally with, front output shaft 56, and a continuous power chain 86 encircling and meshed with first sprocket teeth 88 formed on first sprocket 82 of sprocket drum 100 and with second sprocket teeth 90 formed on second sprocket 82. Transfer assembly 72 is of the chain and sprocket type and provides a direct (1:1) ratio between first sprocket 82 and second sprocket 84. If desired, non-direct ratios may be provided by transfer assembly 72. Transfer case 22, as shown in FIG. 2, is a one-speed configuration with a mainshaft 40 having an input shaft 42 and rear output shaft 36 formed integrally into a common shaft. Input shaft 42 is adapted to be drivingly connected to an output shaft of transmission 20 so as to receive the drive torque from powertrain 12.

[0043] With continued attention primarily to FIG. 2, transfer case 22 is shown with mainshaft 40, mode clutch 70, and clutch actuator 74 operably arranged with respect to a first rotary axis "A". Mode clutch 70 is shown, in this non-limiting configuration, to be a multi-plate friction clutch generally including clutch drum 92 rotatably supported on mainshaft 40, a second clutch member or clutch hub 94 fixed for rotation with mainshaft 40, and a multi-plate clutch pack 96 comprised of a plurality of interdigitated first and second clutch plates. The first clutch plates are coupled via a splined or lugged drive connection 98 (FIG. 3) with clutch hub 94 while the second clutch plates are coupled via a splined or lugged drive connection 102 (FIG. 3) with clutch drum 92. First sprocket teeth 88 of first sprocket 82 and the internal splines/lugs associated with drive connection 102 are formed in sprocket drum 100 to provide the integrated torque transfer component.

[0044] Power-operated clutch actuator 74 is schematically shown in FIG. 2 configured to include a moveable actuation component that is adapted to engage and apply a compressive clutch engagement force on clutch pack 96. As will be understood, movement of this actuation component in an engagement direction (i.e. toward clutch pack 96) increases the magnitude of the clutch engagement force and the corresponding amount of drive torque transferred from mainshaft 40 to front output shaft 56 via transfer assembly 72. Likewise, movement of the actuation component in a releasing direction (i.e. away from clutch pack 96) decreases the magnitude of the clutch engagement force and the corresponding amount of drive torque transmitted from mainshaft 40 to front output shaft 56 via transfer assembly 72.

[0045] Clutch actuator 74 is shown, in this non-limiting embodiment, to generally include moveable actuation component 74A, a force generating mechanism 74B, and a powered driver unit 74C. The moveable actuation component is configured as a pressure plate 74A that is axially-moveable relative to clutch pack 96. Force generating mechanism 74B is actuated by powered driver unit 74C and is operable to generate and exert the axially-directed clutch engagement force for moving pressure plate 74A relative to clutch pack 96. Powered driver unit 74C can include, without limitations, an electric motor, an electromagnetic actuator, a hydraulic power pack (i.e., motor-driven fluid pump) or the like. Similarly, force generating mechanism 74B may include, without limitation, a rotary-to-linear conversion device (i.e., ball ramp unit, spindle-drive unit, etc.) a pivot actuator or a linear actuator.

[0046] Referring now to FIGS. 3 and 4, sectional views of a non-limiting embodiment of transfer case 22 is shown with mainshaft 40 aligned for rotation about first rotary axis “A” while front output shaft 56 is shown aligned for rotation about a second rotary axis “B”. Housing 80 is shown as a two-piece construction having a first housing section 110 secured via a plurality of fasteners 112 to a second housing section 114. First housing section 110 includes an annular input boss segment 116 defining an input aperture 118, and an annular front output boss segment 120 defining a front output aperture 122. Second housing section 114 includes an annular rear output boss segment 124 defining a rear output aperture 126, and an annular front output boss segment 128 defining a bearing support cavity 130. A first bearing assembly 132 is shown rotatably supporting input shaft 42 of mainshaft 40 in input aperture 118, while a second bearing assembly 134 is shown rotatably supporting a yoke coupling 136 fixed to rear output shaft 36 in rear output aperture 126. First and second rotary seals 138, 140 are also respectively disposed within input aperture 118 and rear output aperture 126. A third bearing assembly 142 is shown rotatably supporting one portion of front output shaft 56 within front output aperture 122, while a fourth bearing assembly 144 rotatably supports another portion of first output shaft 56 within bearing support cavity 130. A rotary seal 146 is also disposed within front output aperture 122 while a deflector ring 148 fixed for rotation with front output shaft 56 generally surrounds front output boss segment 120 of first housing section 114. Input shaft 42 of mainshaft 40 is shown to include an internally-splined drive cavity 150 adapted to receive and mesh with an externally-splined output shaft of transmission 20.

[0047] With continued reference to FIGS. 3 and 4, sprocket drum 100 of the stacked and integrated arrangement between transfer assembly 72 and mode clutch 70 is generally shown to include a radial plate segment 152, a smaller diameter axially-extending tubular hub segment 154, and a larger diameter axially-extending sprocket/drum segment 156. Hub segment 154 of sprocket drum 100 surrounds input shaft 42 of mainshaft 40 and is rotatably supported thereon via a fifth bearing assembly 158. The external peripheral surface of sprocket/drum segment 156 includes first sprocket teeth 88 which extend outwardly therefrom while the internal peripheral surface of sprocket/drum segment 156 includes internal spline teeth 160 configured to mesh with the external spline teeth of the second clutch plates of clutch pack 96 to define drive connection 102. First sprocket teeth 88 and internal spline teeth 160 are integrally formed to extend from sprocket/drum segment 156 of sprocket drum 100. Clutch hub 94 is shown to be integrally formed on an intermediate portion of mainshaft 40 and has external spline teeth 162 configured to mesh with the internal spline teeth of the first clutch plates of clutch pack 96 to define drive connection 98 therebetween. Mode clutch 70 is also shown to include a reaction plate 166 fixed for rotation with mainshaft 40 and which is positively axially located within a clutch chamber formed between radial plate segment 152 and sprocket drum segment 156 of sprocket drum 100 via a retainer ring 168. Reaction plate 166 is configured to react to the axially-directed clutch engagement forces applied to clutch pack 96 within the clutch chamber so as to minimize the loading applied to sprocket drum 100.

[0048] Force generating mechanism 74B is shown in FIGS. 3 and 4 to include a ball-ramp unit having a stationary first cam ring 170, a moveable second cam ring 172, and a plurality of balls 174 each disposed between an aligned pair of first cam track 176 and second cam track 178 that are respectively formed in first and second cam rings 170, 172. Stationary first cam ring 170 is restrained rotationally via engagement of an anti-rotational lug 180 extending from second housing section 114 within an anti-rotation aperture 182 formed in first cam ring 170. Likewise, first cam ring 170 is axially restrained adjacent to a locator plate 184. Locator plate 184 is fixed (i.e. splined) for rotation with rear output shaft 36 and is axially restrained via a retainer ring 186. A sixth bearing assembly, in the form of a radial thrust bearing unit 188, is disposed between locator plate 184 and first cam ring 170.

[0049] Second cam ring 172 is configured to be both rotatably moveable and axially moveable relative to first cam ring 170 to create and transfer the clutch engagement force through pressure plate 74A to clutch pack 96. Second cam ring 172 is shown to include an extension 190 having gear teeth 192 formed along its peripheral edge surface. Rotation of second cam ring 172 relative to first cam ring 170 is caused by rotation of a toothed output component of powered driver unit 74C that is meshed with gear teeth 192. As a result of rotation of second cam ring 172 relative to first cam ring 170, rolling movement of balls 174 within the aligned set of “profiled” cam tracks 176, 178 causes second cam ring 172 to translate axially in one of a first or “engaging” direction toward clutch pack 96 and a second or “releasing” direction away from clutch pack 96 based on the direction of rotation controlled by powered driver unit 74C. While not shown, a biasing arrangement is provided for normally biasing either second cam ring 172 or pressure plate 74A in the releasing direction. A seventh bearing assembly, in the form of a radial thrust bearing unit 189, is disposed between second cam ring 172 and pressure plate 74A.

[0050] FIG. 5 illustrates that powered driver unit 74C of clutch actuator 74 includes an electric motor 196 having a rotary motor shaft 198 driving a worm 200. Threads of worm 200 are meshed with gear teeth 192 on extension 190 to define a reduction gearset 202. Motor 196 is secured, such as by fasteners 204, to second housing section 114 of housing 80. In an alternative arrangement, powered drive unit 74C of clutch actuator 74 could drive a rotary mode cam having a profiled cam surface that is maintained in constant engagement with a non-toothed end (i.e. a follower) of extension 190 of second cam ring 172. The cam surface profile of the rotary mode cam would be configured to control rotation and axial movement of second cam ring 172 relative to first cam ring 170.

[0051] Rotation of worm 200 in a first direction causes rotation of second cam ring 172 in a first rotary direction which, in turn, causes corresponding axial movement of second cam ring 172 in its releasing direction (right in drawings) to permit the biasing spring to move pressure plate 74A in a releasing direction and place mode clutch 70 in its released mode. In contrast, rotation of worm 200 in a second rotary direction causes rotation of second cam ring 172 in a second rotary direction which, in turn, causes corresponding axial movement of second ram ring 172 in its engaging direction (left in drawings) for forcibly moving pressure plate 74A in an engaging direction for shifting mode clutch 70 from its released mode into its engaged mode. As noted, the configuration of the aligned pairs of first and second cam tracks 176, 178 acts to coordinate the relationship between rotation and axial translation of second cam ring 172 relative to first cam ring 170.

[0052] FIG. 6 is a partial sectional view of a slightly revised version of transfer case 22 shown in FIGS. 3 and 4, and which is identified hereafter as transfer case 22A. Similar components of transfer case 22A to those previously disclosed will be identified with common reference numerals. Transfer case 22A is now equipped with a separate clutch hub 94A that is splined to rear output shaft 36 and has a reaction plate 166A integrally formed therewith. A return spring 200 is shown for normally biasing pressure plate 74A in the releasing direction. A gerotor lube pump 202 is driven by rear output shaft 36A and delivers lubricant from a sump to a central lube passage 204 formed in rear output shaft 36A for subsequent delivery of the lubricant to ball ramp unit 74B and mode clutch 70. Hub segment 154A of sprocket drum 100 is a separate component. Likewise, sprocket drum 100 includes a bell-shaped component which defines radial plate segment 152A and drum segment 156A. Hub segment 154A and radial plate segment 152A are rigidly secured together such as by welding.

[0053] Additionally, first cam ring 170A is shown to include a first lever extension 210 and second cam ring 172A is shown to include a second lever extension 212. Lever extensions 210, 212 extend toward and engage opposite portions of a rotary mode cam driven by powered driver unit 74C. In one arrangement, a flat end segment on first lever extension 210 engages a non-profiled portion of the rotary mode cam to prevent rotary movement of first cam ring 170A while a follower mounted to a second lever extension 212 would engage a profiled portion of the rotary mode cam to control rotary movement of second cam ring 172A relative to first cam ring 170A. In an alternative arrangement, first lever extension 210 would have a follower engaging a profiled portion of the rotary mode cam and a flat end on second lever extension 212 would engage a non-profiled portion of the mode cam, whereby rotation of first cam ring 170A relative to second cam rang 172A controls axial movement of second cam ring 172A. Finally, both lever extensions 210, 212 could engage profiled portions of the rotary mode cam to provide a “scissor-like” action controlling axial movement of second cam ring 172A relative to first cam ring 170A.

[0054] Referring to FIG. 7, a sectional view of another modified version of transfer case 22A of FIG. 6 is hereinafter identified as transfer case 22B. Similar components of transfer case 22B to those previously disclosed will be identified with common reference numerals. Transfer case 22B is generally similar to transfer case 22A with the exception that first sprocket 82B is a separate component from clutch drum 92B of mode clutch 70. In addition, powered driver unit 74C of clutch actuator 74 is shown in greater detail to include a rotary actuator shaft 250 driven by an electric motor 252 and a rotary mode cam 254 fixed for rotation with actuator shaft 250. Lever extension 210B of first cam ring 170B has a follower (not shown) engaging a profiled cam surface on mode cam 254. Thus, rotation of mode cam 254 via actuation of motor 252 controls rotation of first cam ring 170B relative to second cam ring 172B. Lever extension 212B on second cam ring 172B engages a non-profiled locator collar 256 so as to be held against rotation, but still be axially moveable relative to first cam ring 170B. While not specifically shown, a plurality of first cam tracks in first cam ring 170B are each aligned with corresponding plurality of second cam tracks formed in second cam ring 172B. Balls 174B are retained between the aligned first and second cam tracks. The profile of these first and second cam tracks, in conjunction with the profile of the cam surface on rotary mode cam 254, cooperate to define the relationship between rotation of first cam rings 170B and axial movement of second cam ring 172B. Powered driver unit 74C shown in FIG. 7 is generally similar to the arrangement used to control operation of the ballramp unit shown in FIG. 6.

[0055] In each of the ballramp units disclosed in association with transfer cases 22 (FIGS. 3-4), 22A (FIG. 6) and 22B (FIG. 7), a pair of cam rings are used to generate and apply the clutch engagement force to mode clutch 70. Conventionally, cam rings 170/172, 170A/172A, and 170B/172B have been made as forged components that are subsequently machined to accurately produce various "structural" features. These structural features have included, without limitation, the cam tracks, anti-rotation tabs, locator tabs, flats and apertured bosses on the lever extensions, and pilot bosses, as well as weight reduction features. Obviously, the material removed via machining creates waste. Likewise, the machining processes require investment in machining stations and perishable tools, in addition to the expensive direct manpower required. Accordingly, the present disclosure is generally related to producing these structural features using cold forming processes in substitution for conventional machining processes. By changing to cold forming solutions while maintaining all finished dimensional requirements, capital and manpower can be greatly reduced. Additionally, quality will also improve as cold forming is a fixed process, without added variation commonly associated with CNC machining operations.

[0056] FIGS. 8A and 8B illustrate a first cam ring 170C and a second cam ring 172C (which are generally similar in function to cam rings 170A, 172A of FIG. 6) that have been manufactured from forged components with one or more of their structural features made via cold forming operations. Specifically, first cam ring 170C (FIG. 8A) is shown to have cold formed structural features including a plurality of first cam tracks 176C, a plurality of locator tabs 300, a locator flat 302 on lever extension 210C, and a tubular pilot hub 304. Likewise, second cam ring 172C (FIG. 8B) is shown to have cold formed structural features including a plurality of second cam tracks 178C, a plurality of locator tabs 306, an apertured follower boss 308, and a locator boss 310 on lever extension 212C. FIGS. 9A and 9B provide additional disclosure related to several of the cold formed structural features associated with first cam ring 170C. Likewise, FIGS. 10A and 10B provide additional disclosure related to several of the cold formed structural features associated with second cam ring 172C.

[0057] Referring now to FIG. 11A, a process flowchart 350 for manufacturing first cam ring (170, 170A, 170B) using an existing or otherwise conventional sequence of operations is shown to include at least Operations 351-355. Specifically, Operation 351 identifies the hot forging of a first cam ring preform with a general shape having additional material provided for subsequent removal via the machining operations. Operation 352 identifies a first machining stage or station whereat one or more features are machined using the hot forged preform from Operation 351. In this non-limiting example, the first machining station of Operation 352 is configured to: machine the "A" face surface; machine the ID; and machine the part to length. Operation 353 is a second machining stage or station whereat one or more additional features are machined using material removal processes. In this non-limiting example, the second machining station of Operation 353 is configured to: machine a plurality of cam tracks; machine a plurality of locator tabs; machine a locator flat; and machine the OD of the tubular pilot bore. Operation 354 is a heat treating process following completion of the machining operations, preferably employing a vacuum heat treating operation with helium quench for minimized distortion. Finally, Operation 355 identifies a final grinding process utilized after completion of the heat treating.

[0058] In comparison to the conventional process flowchart 350 of FIG. 11A, FIG. 11B illustrates a process flowchart 450 for manufacturing first cam ring 170C using an improved/enhanced sequence of operations in accordance with the present disclosure and which includes at least one or more cold forming operations, in substitution for conventional machining operations, to form structural features. Specifically, Operation 451 identifies hot forging of a "near net" preform for first cam ring 170C that has been modified for the subsequent cold forming operations. This modified hot forged preform could include, for example, location indicators for the cam tracks and additional/reduced material strategically located for the subsequent cold forming operations. This additional or reduced material can be in the form of depressions or projections. Operation 452 is a “pre” cold forming machining operation, similar to Operation 352 of process flowchart 350 (FIG. 11A), with the exception of machining the length of the modified preform. Operation 453 identifies the cold forming of several important structural features including the final length dimension, the cam tracks, the locator tabs and flats, and/or the OD pilot. Upon completion of the cold forming operations, first cam ring 170C is heat treated (Operation 354) and finish ground (Operation 355) in a manner similar to the machined first cam rings.

[0059] In comparison to the conventional process flowchart 350 of FIG. 11A, and the improved process flowchart 450 of FIG. 11B, FIG. 11C illustrates an alternative improved process flowchart 550 for manufacturing first cam ring 170C using an improved/enhanced sequence of operations including at least one or more cold forming operations. Generally speaking, process flowchart 550 identifies a slightly varied version of process flowchart 450 (FIG. 11B) capable of being considered an alternative method embodying the teachings of the present disclosure. Operations 551 and 552 of process flowchart 550 are substantially similar to Operations 451 and 452 of process flowchart 450 such that no further discussion is required. However, the cold forming Operation 553 differs from cold forming Operation 453 in that the cam track features are not formed completely to final dimensions, but rather to a dimension equivalent to that of a two pass rough machining operation. Thus, Operation 554 is employed after completion of the cold forming operations to machine the cam tracks to final dimensions, much like a finish machining pass. Thereafter, process flowchart 550 illustrates that first cam ring 170C is heat treated (Operation 354) and finish ground (Operation 355) in a manner similar to conventionally manufactured first cam rings.

[0060] Referring now to FIG. 12A, a process flowchart 370 for manufacturing second cam ring (170, 170A, 170B) using an existing or otherwise conventional sequence of operations is shown to include at least Operations 371-375. Specifically, Operation 371 identifies the hot forging of a second cam ring preform with a general shape having additional material provided for subsequent removal via machining operations. Operation 372 identifies a first machining stage or station whereat one or more features are machined into the preform from Operation 371. These features include: machining the "A" face surface, machining the ID; and machining the part to length. Operation 373 is a subsequent, second machining stage or station whereat one or more additional features are machined using material removal processes. In this example, the secondary machining processes of Operation 373 include: machining the cam tracks; machining locator tabs; machining the roller/follower boss; and drill/chamfer of the rear pin hole. Operation 374 is a heat treating process following completion of the machining operations, preferably employing a vacuum heat treating operation and a helium quenching operation. Finally, Operation 375 identifies a face grinding and bearing bore grinding operation.

[0061] In comparison to the conventional process flowchart 370 of FIG. 12A, FIG. 12B illustrates a process flowchart 470 for manufacturing second cam ring 172C using an improved/enhanced sequence of operations in accordance with the present disclosure and including at least one or more cold forming operations, in substitution for the conventional machining operations, to form various structural features. Specifically, Operation 471 identifies hot forging a second cam ring "near net" preform modified for subsequent cold forming operations. This modified hot forged preform could include, for example, location indicators for the cam tracks and additional/reduced material strategically located for the subsequent cold forming operations. Operation 472 is a “pre” cold forming machining operation, similar to Operation 372 of process flowchart 370 (FIG. 12A), with the exception of machining the length of the modified preform. Operation 473 identifies the step of cold forming several important structural features including the final dimension of length, the cam tracks, the locator tabs and the roller/follower boss. Upon completion of the cold forming operation, Operation 474 indicates drill and chamfer machining of the rear pin hole. Thereafter, second cam ring 172C is heat treated (Operation 374) and finish ground (Operation 375) in a manner similar to the same operations associated with second cam rings manufactured using the conventional process flowchart 370.

[0062] In comparison to the conventional process flowchart of FIG. 12A, and the improved process flowchart of FIG. 12B, FIG. 12C illustrates an alternative improved process flowchart 570 for manufacturing second cam rings 172C using an improved/enhanced sequence of operations in accordance with the present disclosure and including at least one cold forming operation. Generally speaking, process flowchart 570 is a slightly varied version of process flowchart 470 (FIG. 12B) that is capable of being considered an alternative preformed embodiment of the present disclosure. Operations 571 and 572 are substantially similar to Operations 471 and 472 of process flowchart 470. However, cold forming Operation 573 differs from cold forming Operation 473 in that the cam tracks are not completely cold formed to final dimensions, but rather to a dimension equivalent to that of a two pass rough machining operation. Operation 574 is generally similar to Operation 474, but further adds the final machining of the cam tracks. Thereafter, process flowchart 570 indicates that second cam ring 172C is heat treated (Operation 374) and finish ground (Operation 375) in a manner similar to conventionally manufactured second cam rings.

[0063] FIGS. 13A and 13B illustrate further revised versions of first cam ring 170C and second cam ring 172C that have been cold formed to include weight reduction apertures/holes 314, 316 respectively. Similarly, FIGS. 14A-14C illustrate still further revised versions of first cam ring 170C with undercuts 320 and second cam ring 172C with undercuts 322.

[0064] 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. In a motor vehicle having a powertrain normally transmitting drive torque from a powertrain to a primary driveline, a power transfer assembly operable to selectively transmit drive torque to a secondary driveline, the power transfer assembly comprising:

a friction clutch assembly having a first clutch member receiving drive torque from the powertrain, a second clutch member drivingly interconnected to the secondary driveline, and a multi-plate clutch pack operably disposed between the first and second clutch members; and

a power-operated clutch actuator including an actuation component moveable relative to the clutch pack, a force generating mechanism operable to generate and cause the actuation component to apply a clutch engagement force on the clutch pack, and a powered drive unit for controlling actuation of the force generating mechanism,

wherein the force generating mechanism includes a ballramp unit having first and second cam rings at least one of which is cold formed to define a structural feature.

2. The power transfer assembly of Claim 1, wherein the first cam ring is cold formed to include a plurality of first cam tracks.

3. The power transfer assembly of Claim 2, wherein the second cam ring is cold formed to include a plurality of second cam tracks, and wherein the second cam tracks are alignable with the first cam tracks.

4. The power transfer assembly of Claim 3, wherein at least one of the first and second cam rings are cold formed to define further structural features including at least one of locating tabs, flats, OD pilot segments, bosses or apertures.

5. The power transfer assembly of Claim 2, wherein the first cam ring is cold formed to define additional structural features including at least one of locating tabs, flats, OD pilots, or apertures.

6. The power transfer assembly of Claim 1, wherein the first cam ring is hot forged with visual indicator portions.

7. The power transfer assembly of Claim 6, wherein the visual indicator portions of the first cam are cold formed to define ball ramp pockets.

8. The power transfer assembly of Claim 6, wherein the second cam ring is hot forged with second visual indicator portions alignable with the first visual indicator portions.

9. The power transfer assembly of Claim 8, wherein the second visual indicator portions of the second cam ring are cold formed to define second ball ramp pockets.

10. A method of assembling at least one cam ring in a clutch actuator, the clutch actuator adapted to control compressive clutch engagement force on a multi-plate clutch pack in order to regulate drive torque from a primary driveline to a secondary driveline comprising the steps of:

hot forging at least one cam ring having a ring portion and a lever extension;

hot forging at least one localized visual indicator on at least one of the ring portion or the lever extension that designate localized locations on the at least one cam ring to receive a cold forming operation; and

using the localized visual indicators as a reference, cold forming features into the localized locations.

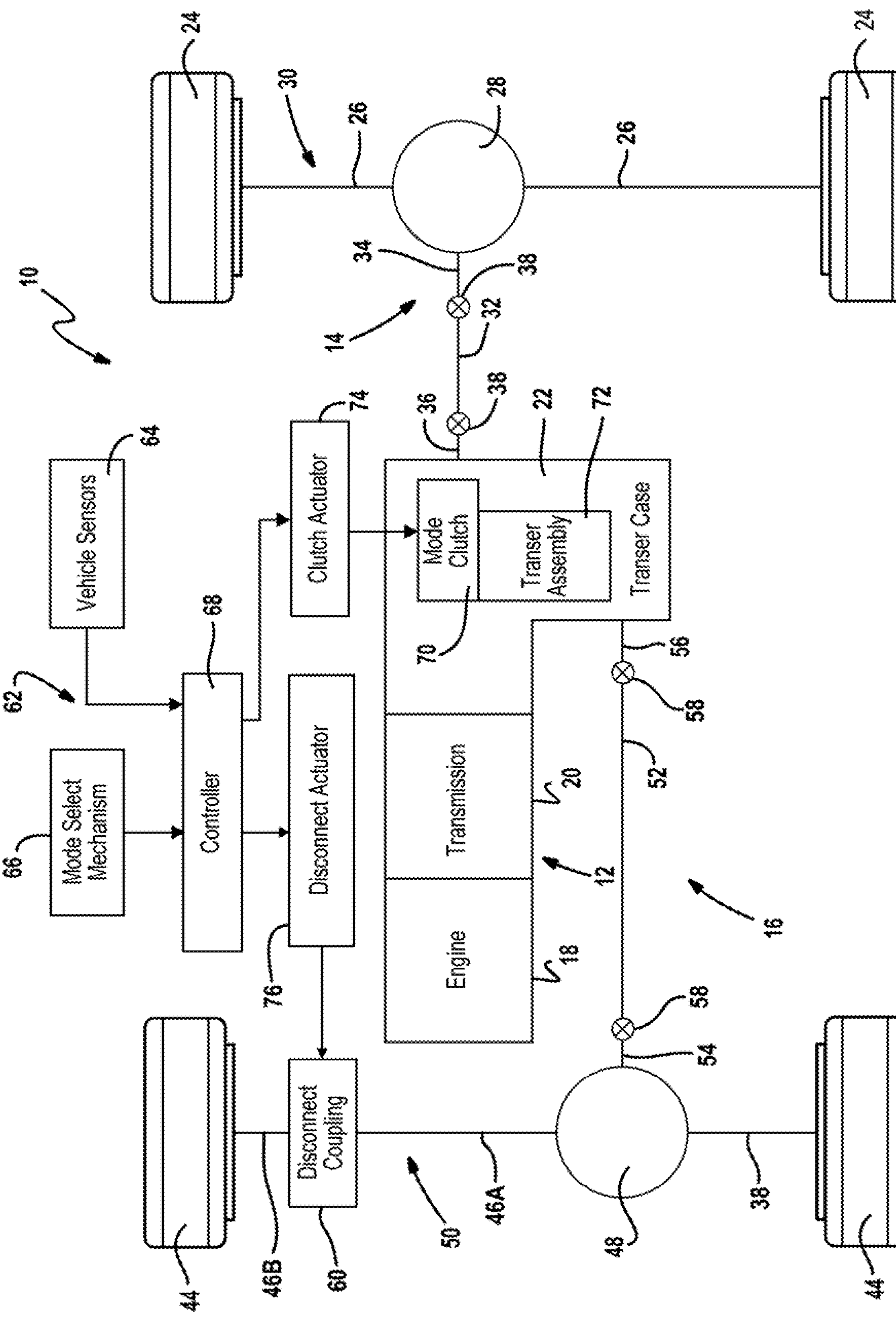
11. The method of Claim 10, wherein the step of hot forging at least one localized visual indicator includes hot forging one of depressions and projections.

12. The method of Claim 11, wherein the step of cold forming includes cold forming ball ramp pockets on the ring portion.

13. The method of Claim 11, wherein the step of cold forming includes cold forming at least one locator tab on the ring portion.

14. The method of Claim 12 including hot forging a second cam ring having a second ring portion and hot forging localized visual indicators on the second ring portion that correspond to the location of the ball ramp pockets on the other cam ring.

15. The method of Claim 10, wherein the step of hot forging results in the lever extension at a first length and the step of cold forming results in the lever extension at a second length larger than the first length.


Vehicle Sensors
Mode Select Mechanism
Controller
Clutch Actuator
Disconnect Actuator
Mode Clutch
Transer Assembly
Transer Case
Transmission
Engine
Disconnect Coupling
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
44
46A
46B
48
50
52
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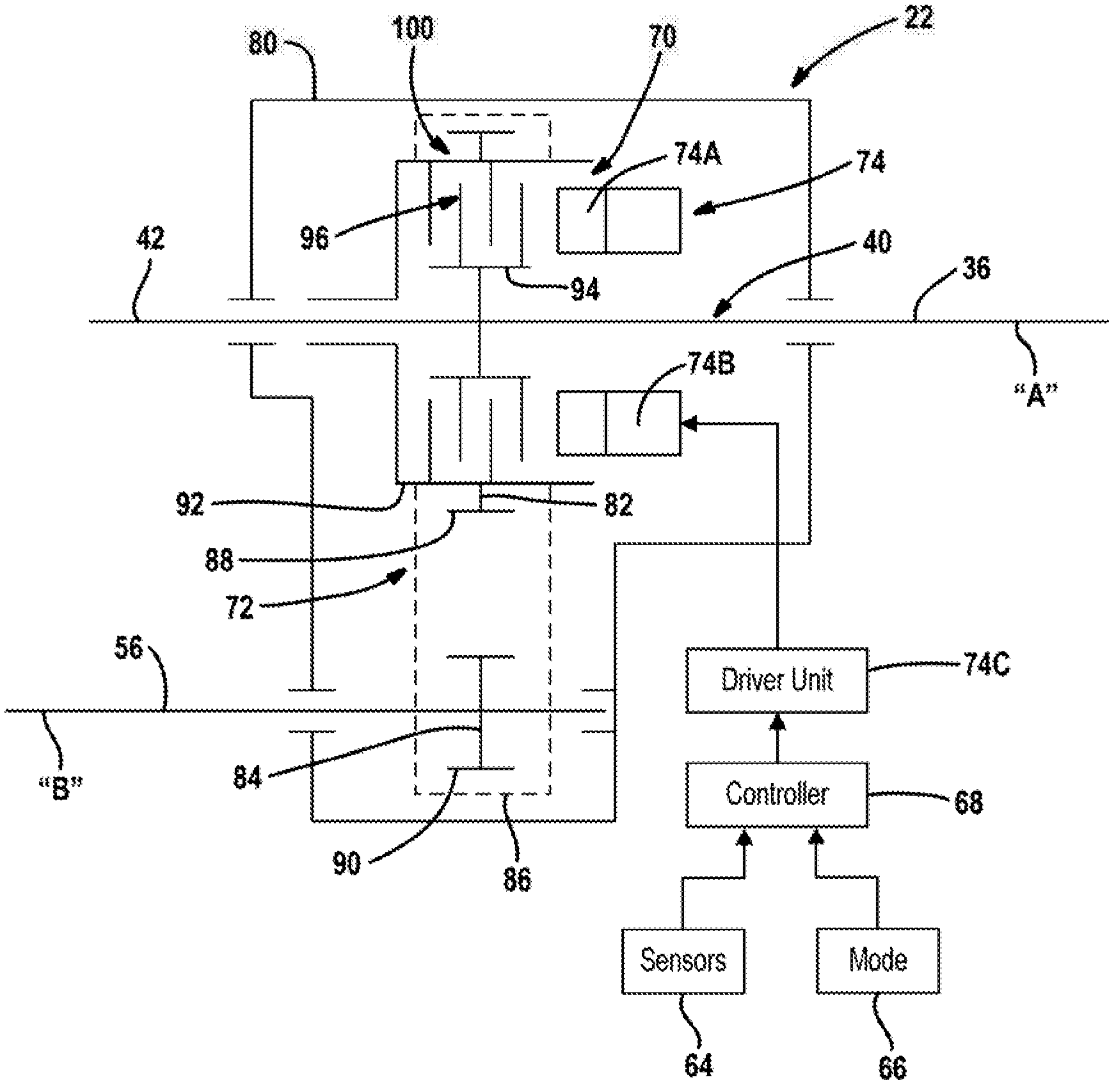
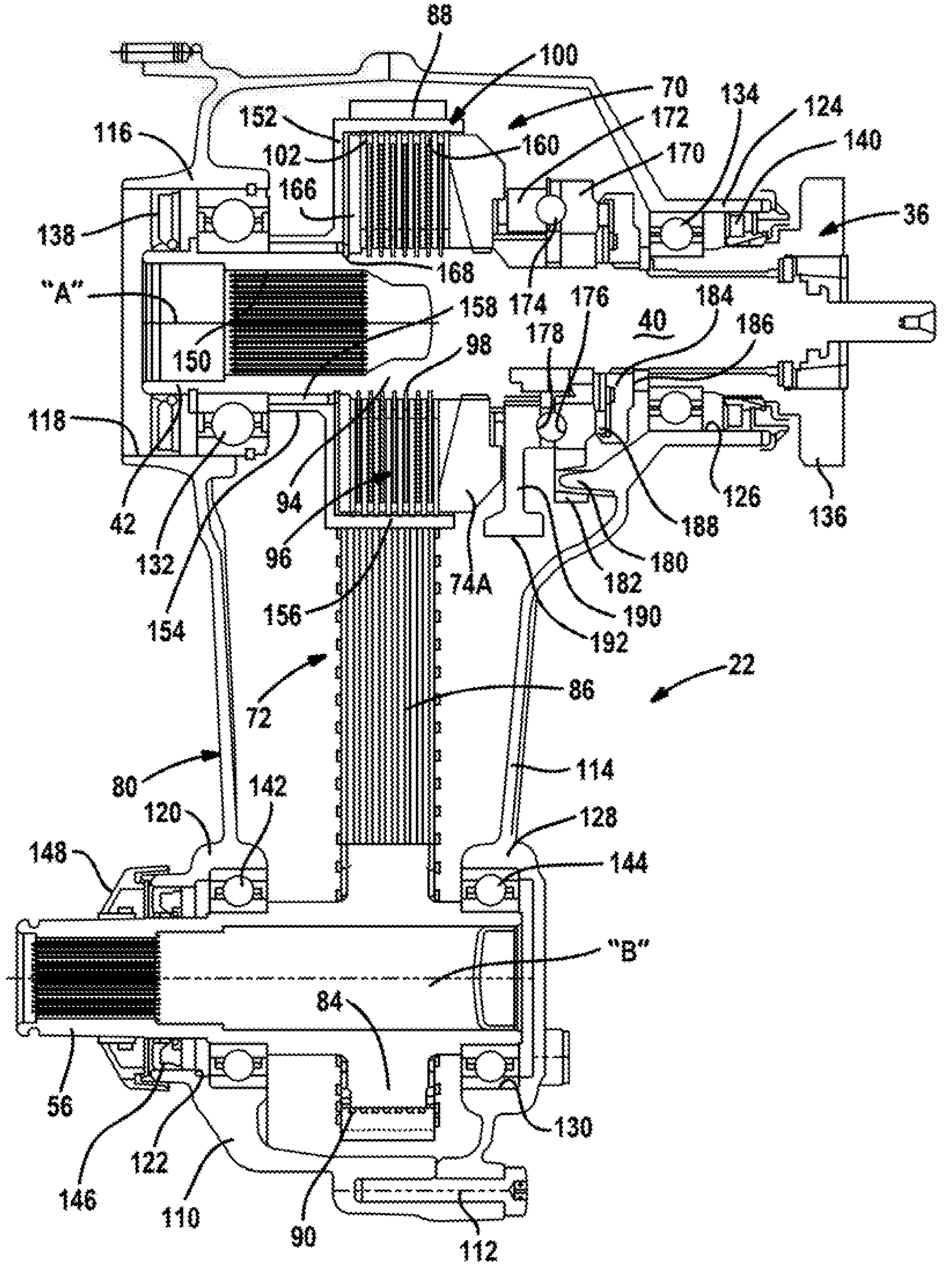
72
74
76

FIG. 1



80
100
70
22
74A
74
96
42
40
36
94
74B
"A"
92
82
88
72
56
Driver Unit
74C
Controller
68
84
"B"
90
86
Sensors
Mode
64
66

FIG. 2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100
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172
134
124
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102
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170
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166
36
138
168
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174
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178
40
186
150
98
118
42
94
188
126
136
132
96
180
182
154
156
74A
190
192
22
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72
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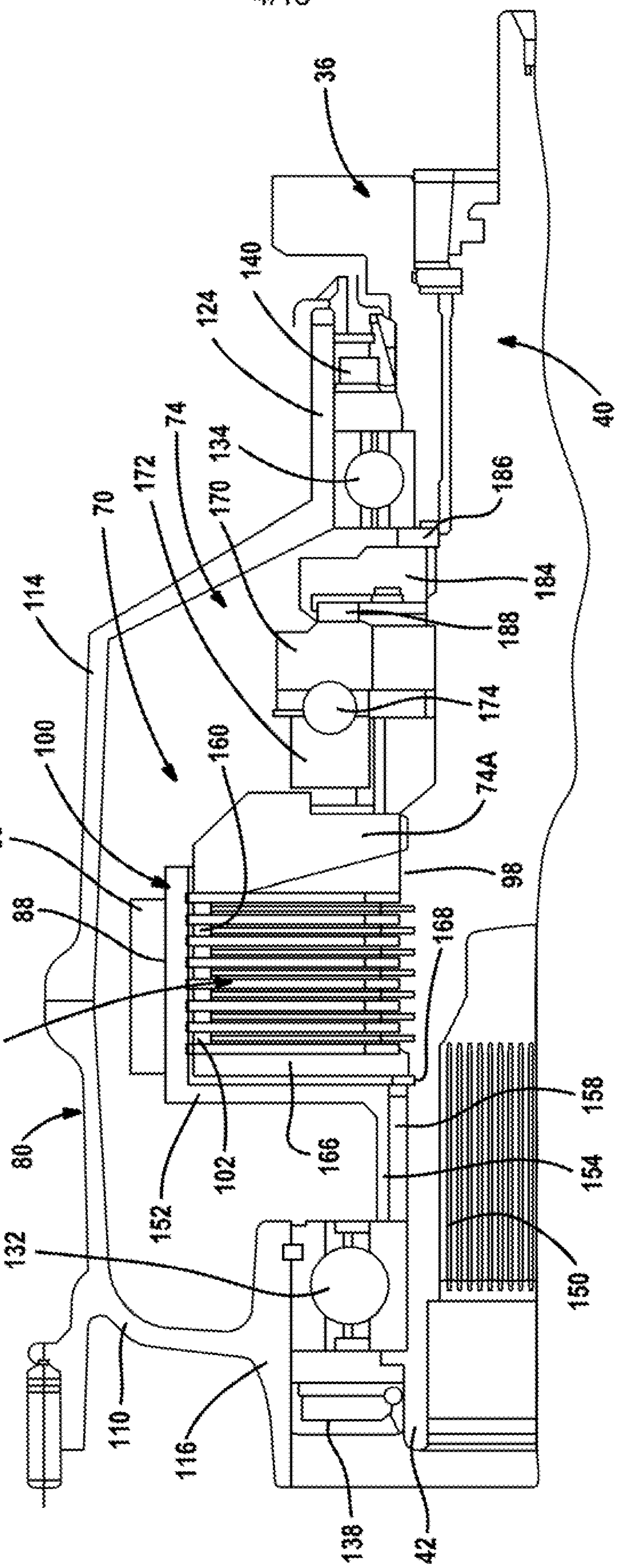
112

FIG. 3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140
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74
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160
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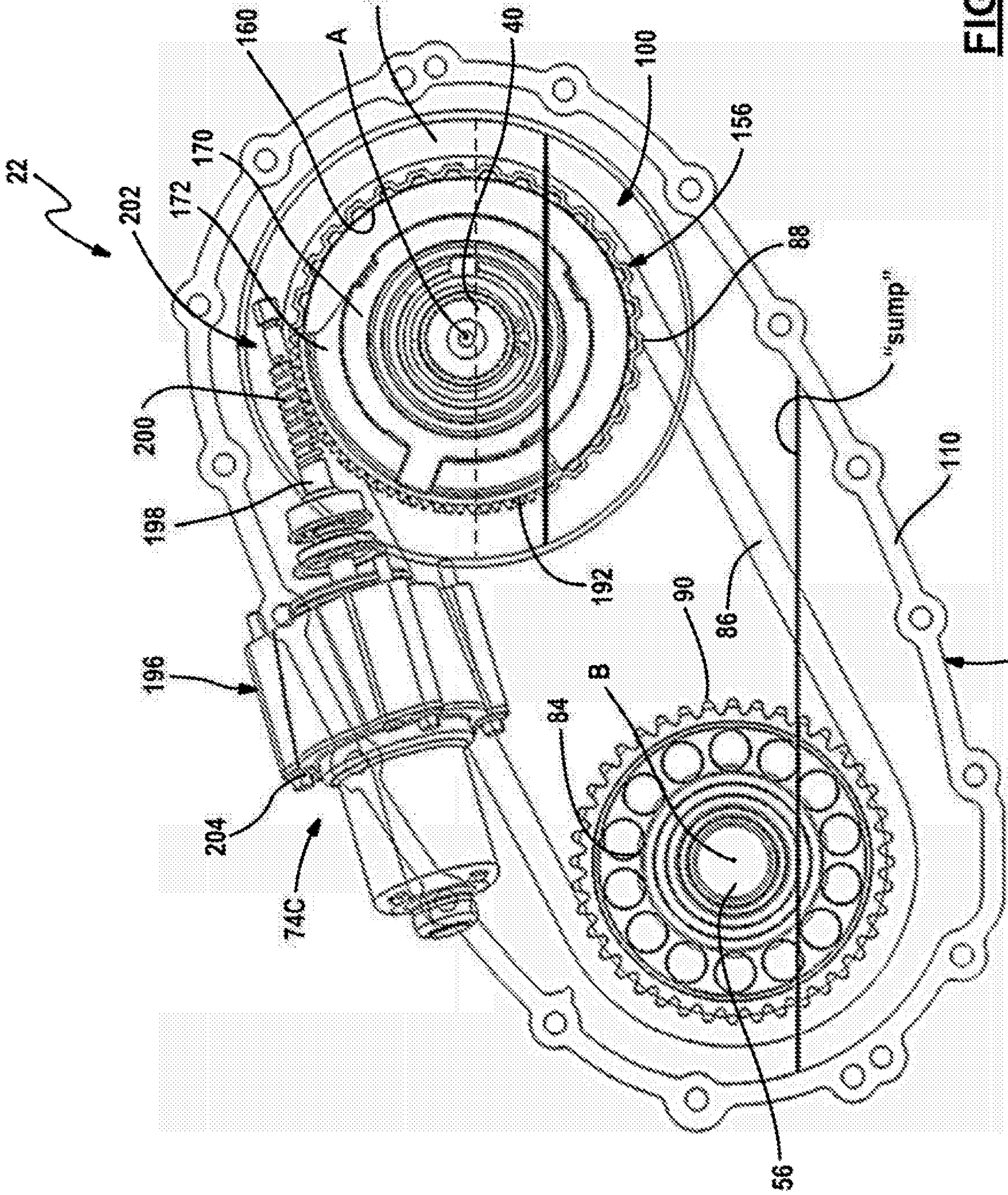
74A
98
168
158
154
150
80
152
102
166
132
110
116
138
42

FIG. 4


22
202
172
170
160
A
74A
40
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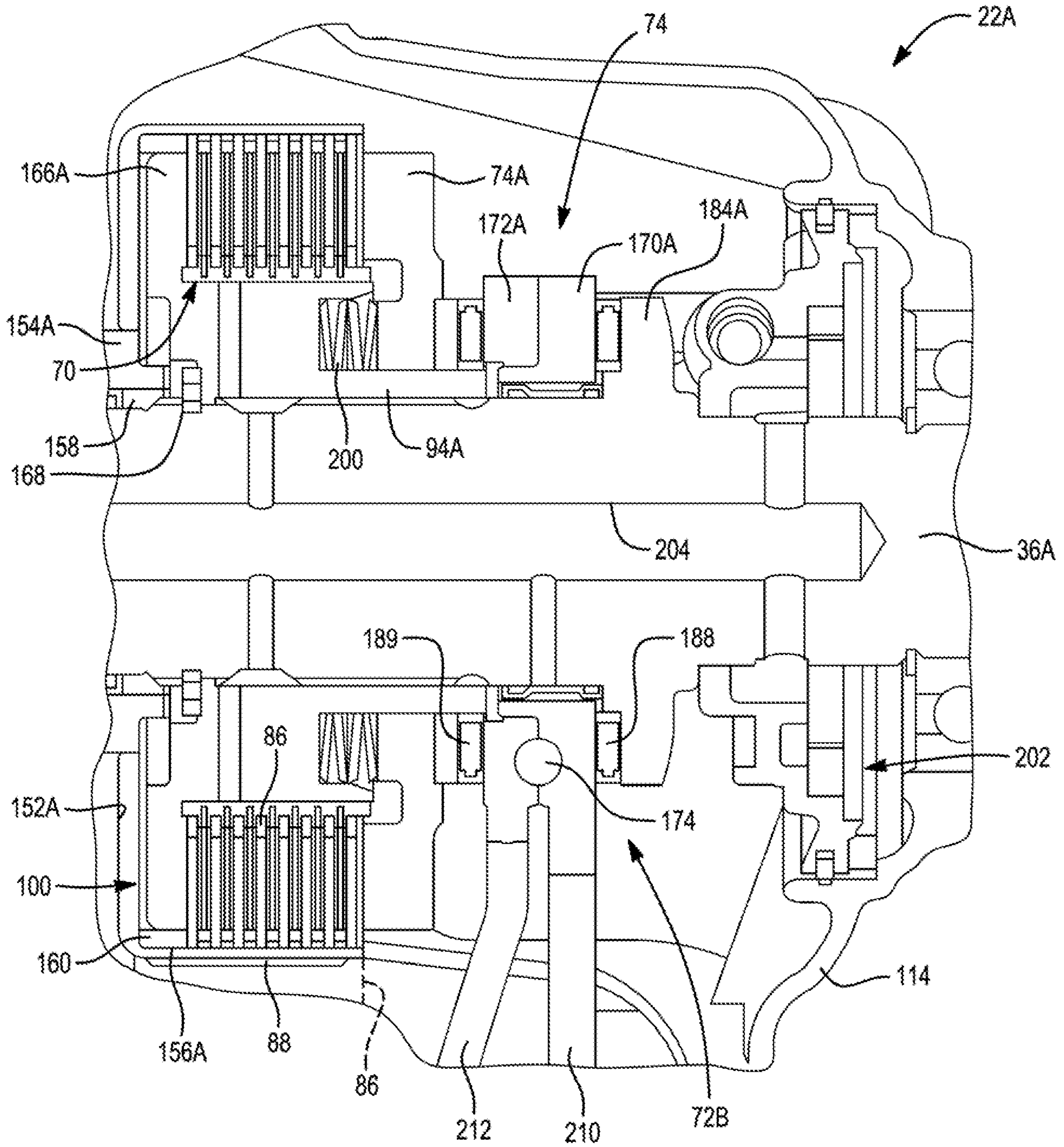
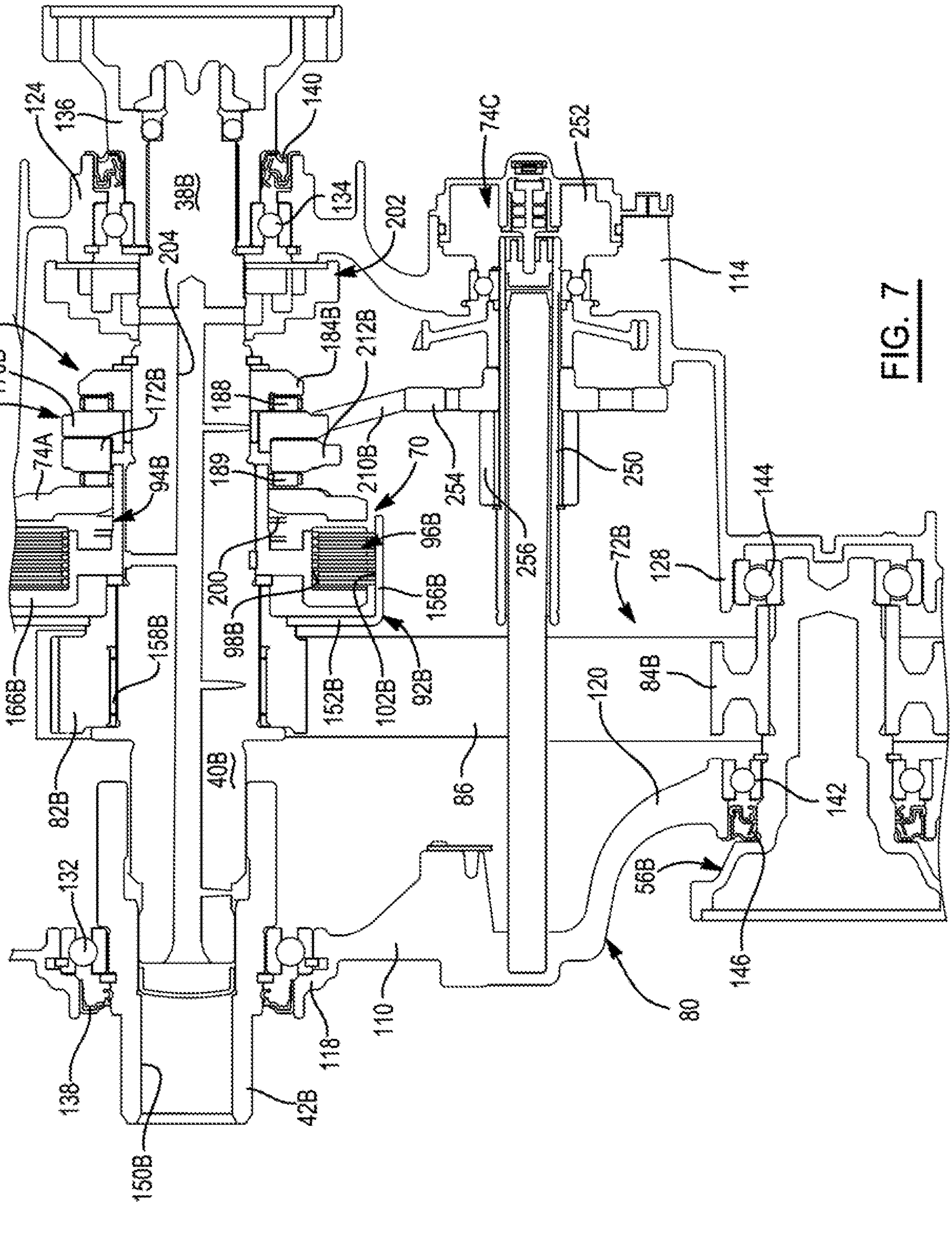
156
88
"sump"
110
200
198
192
90
86
80
196
84
B
204
74C
56

FIG. 5



22A
74
166A
74A
172A
170A
184A
154A
70
158
168
200
94A
204
36A
189
188
86
202
152A
174
100
160
114
156A
88
86
212
210
72B

FIG. 6


124
136
140
74C
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38B
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74
74B
170B
172B
184B
212B
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74A
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189
210B
70
254
250
144
256
72B
128
96B
200
156B
98B
158B
166B
102B
92B
152B
84B
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56B
132
146
110
80
118
138
42B
150B

FIG. 7

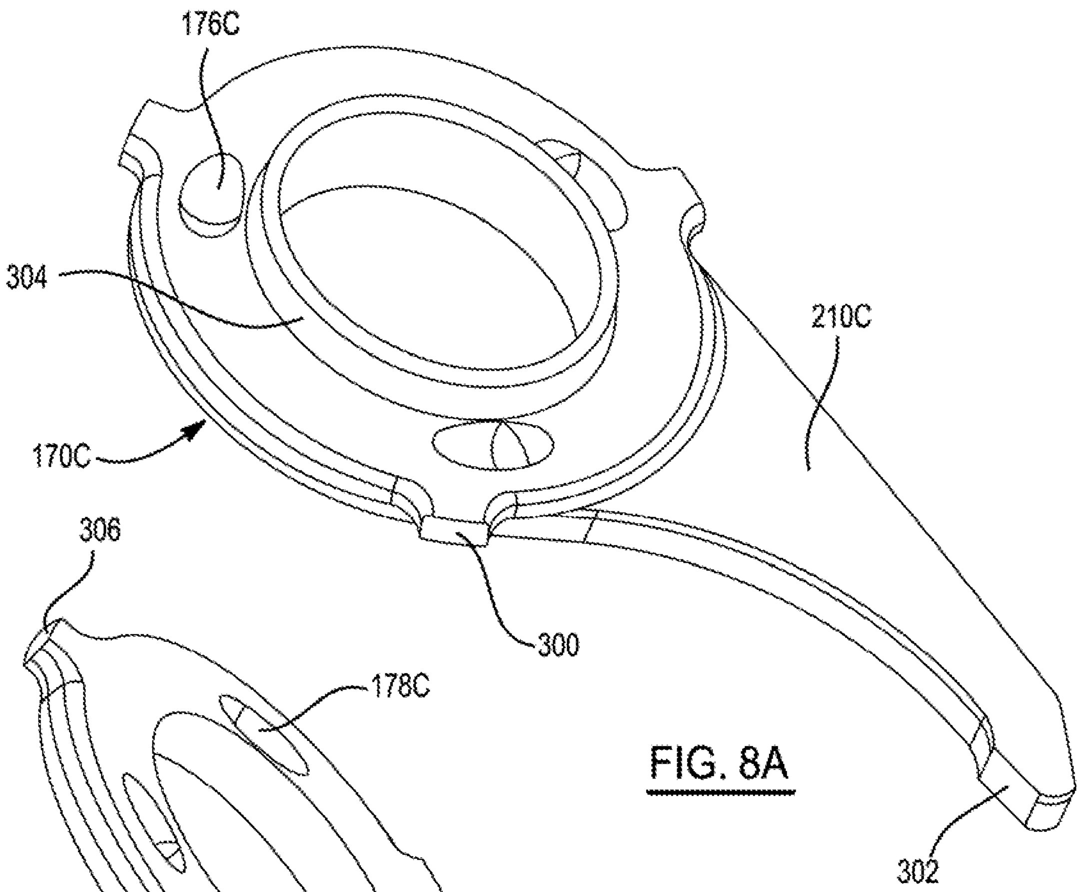

FIG. 8A

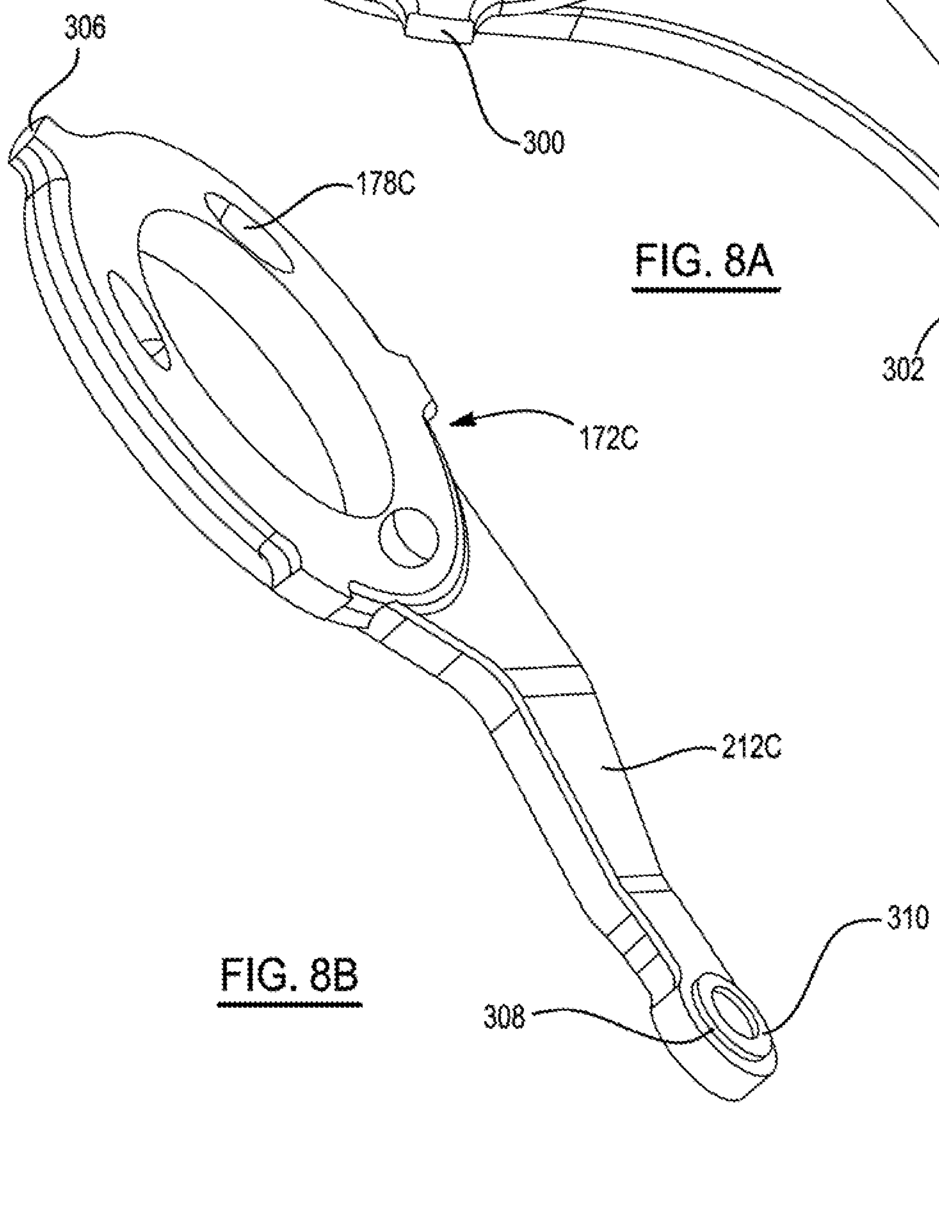

FIG. 8B

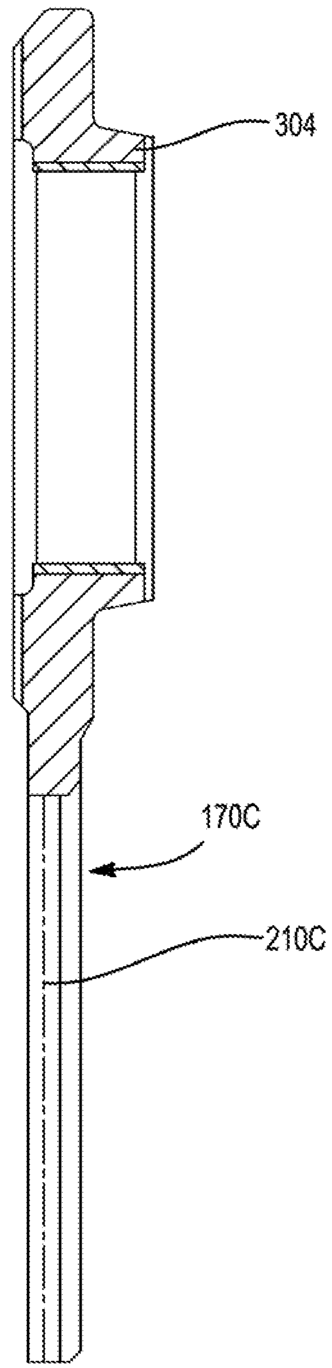

FIG. 9A

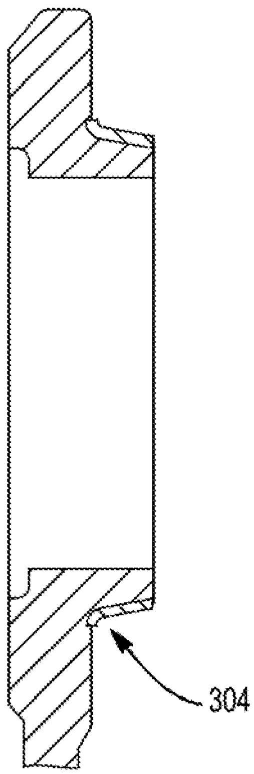

FIG. 9B

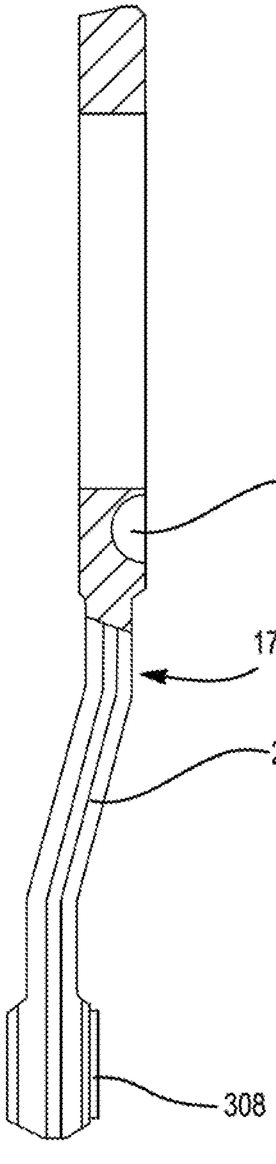

FIG. 10A

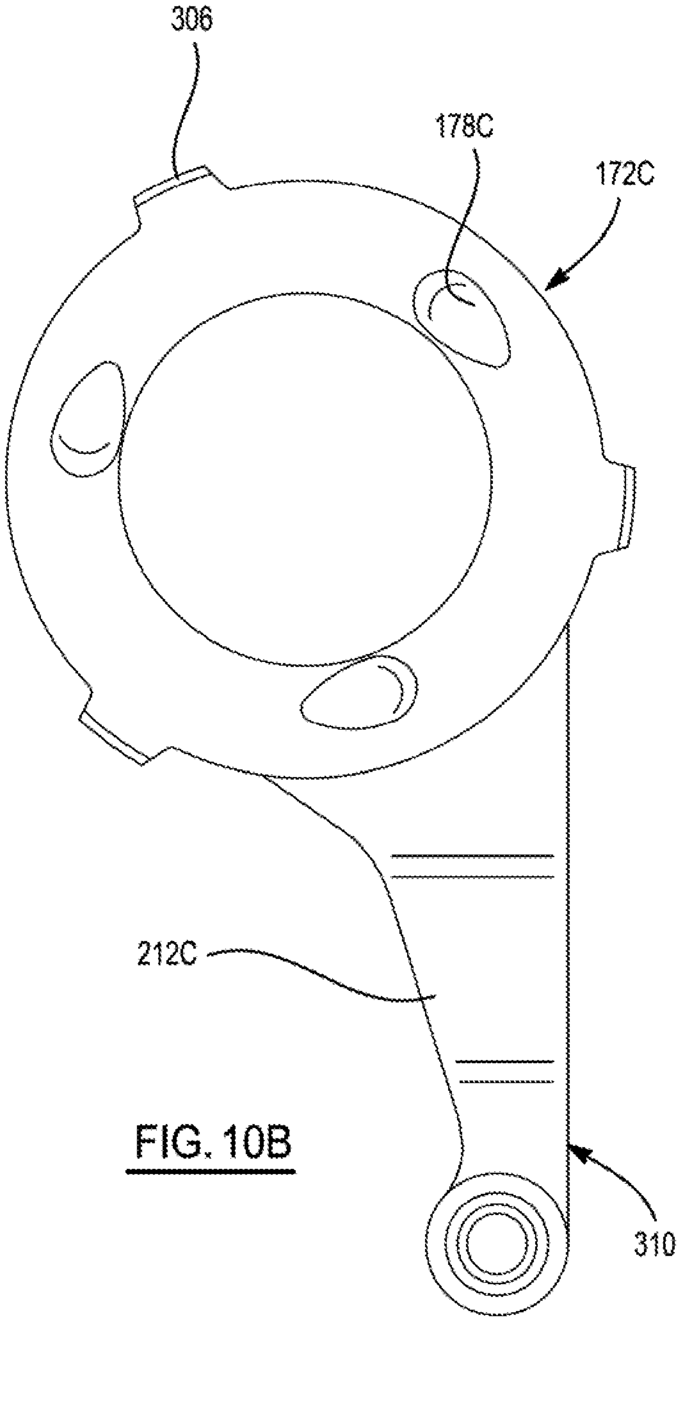

FIG. 10B

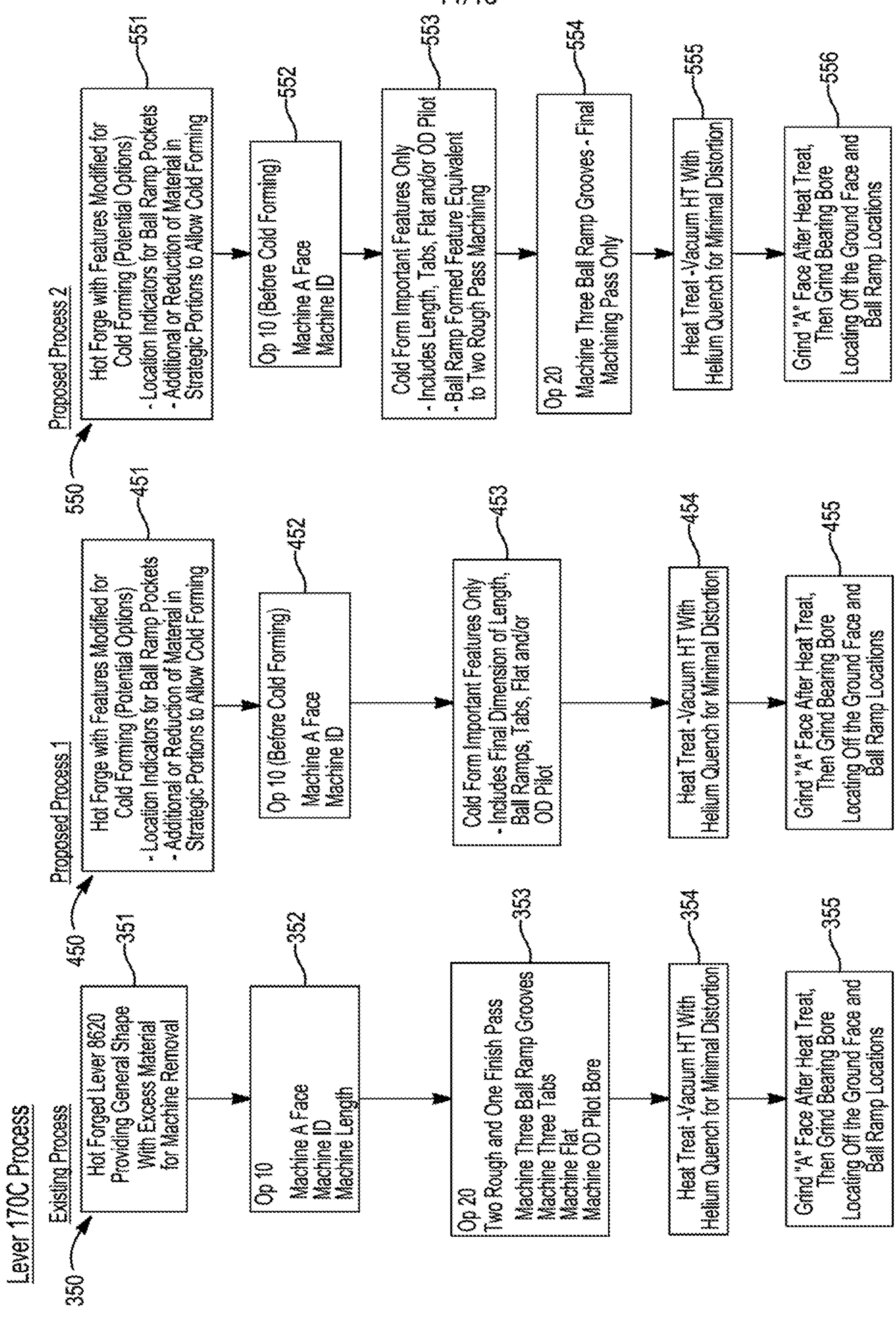

FIG. 11A

FIG. 11B

FIG. 11C

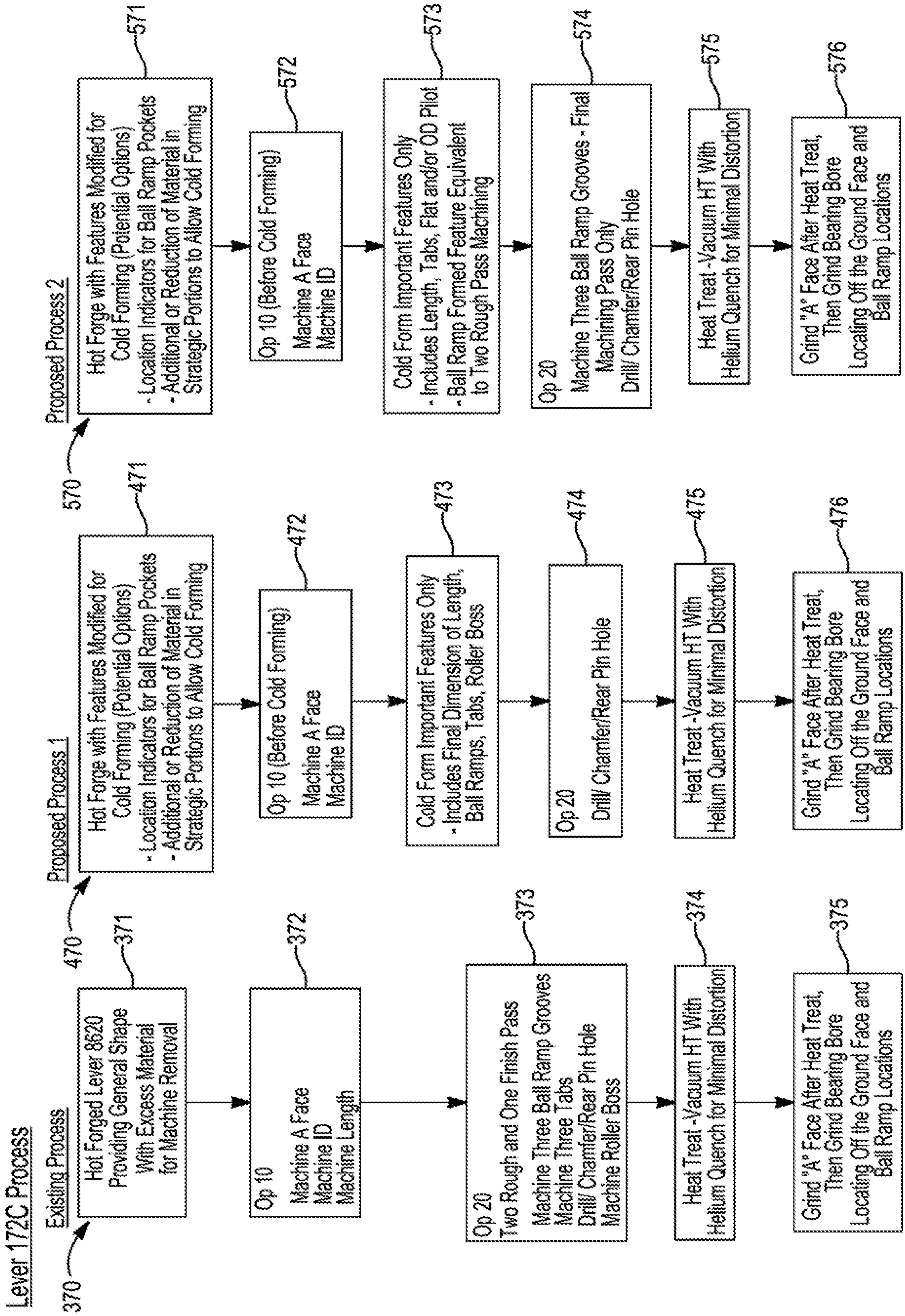

FIG. 12A

FIG. 12B

FIG. 12C

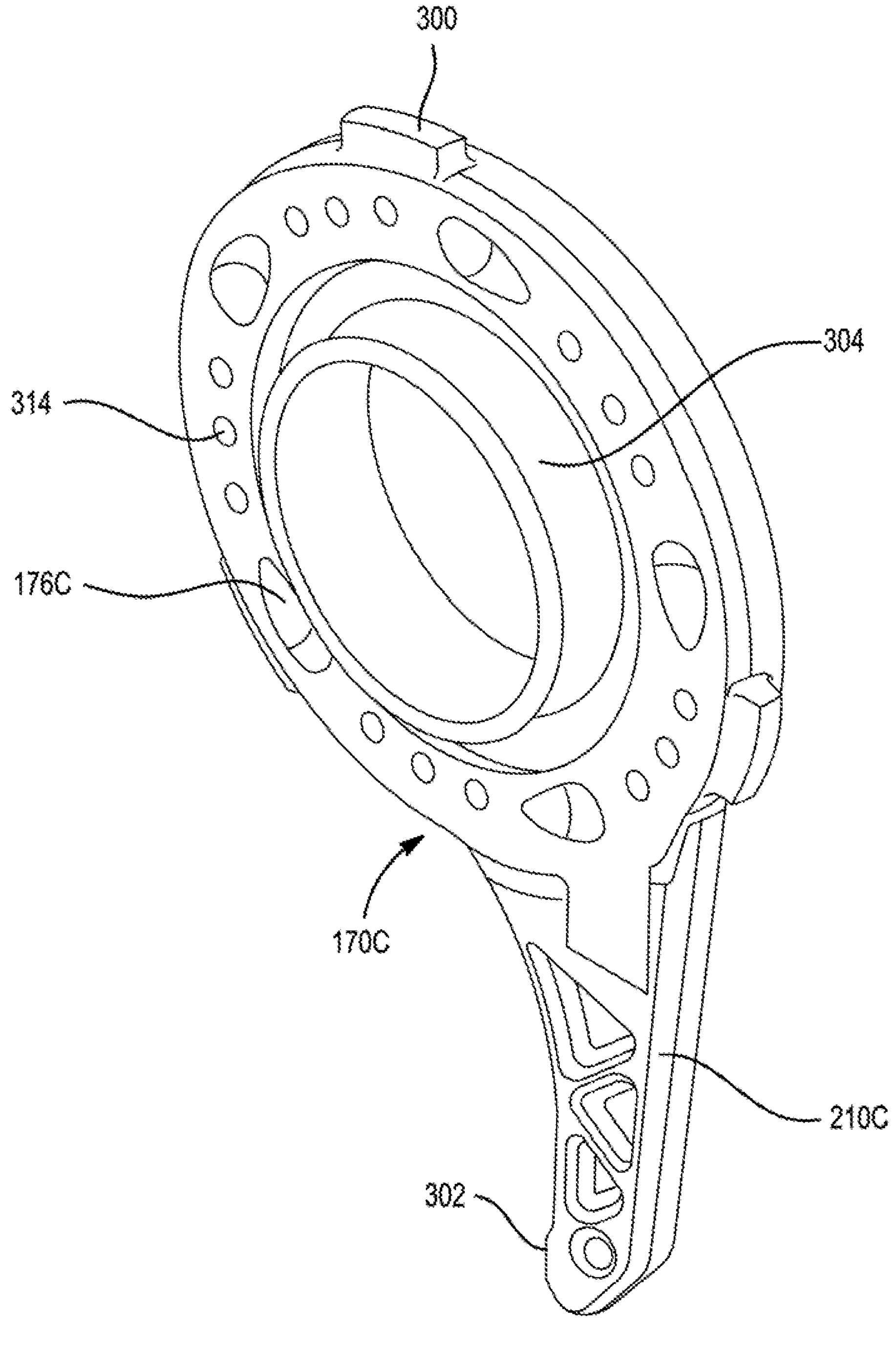

FIG. 13A

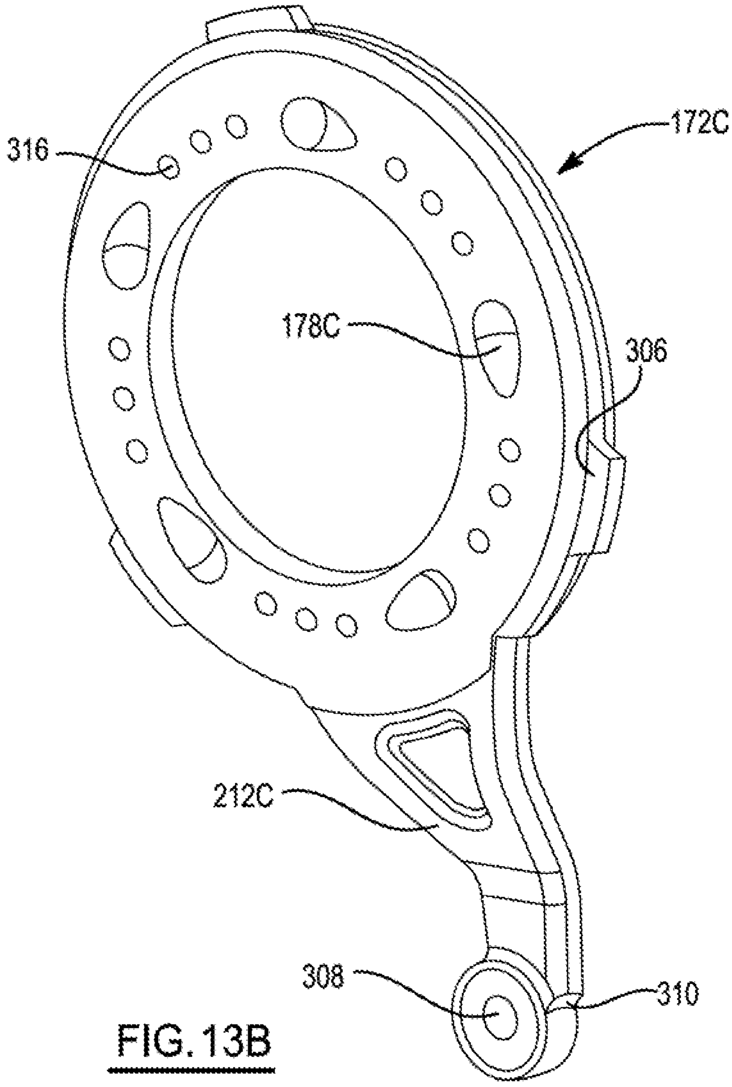

FIG. 13B

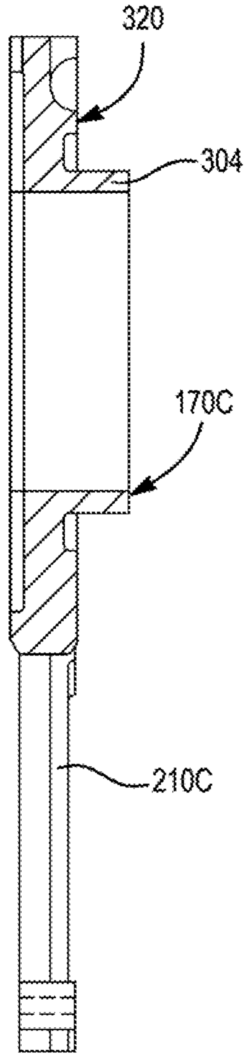

FIG. 14A

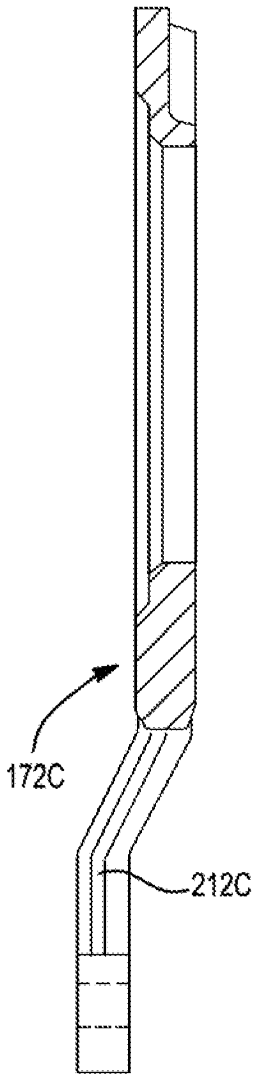

FIG. 14B

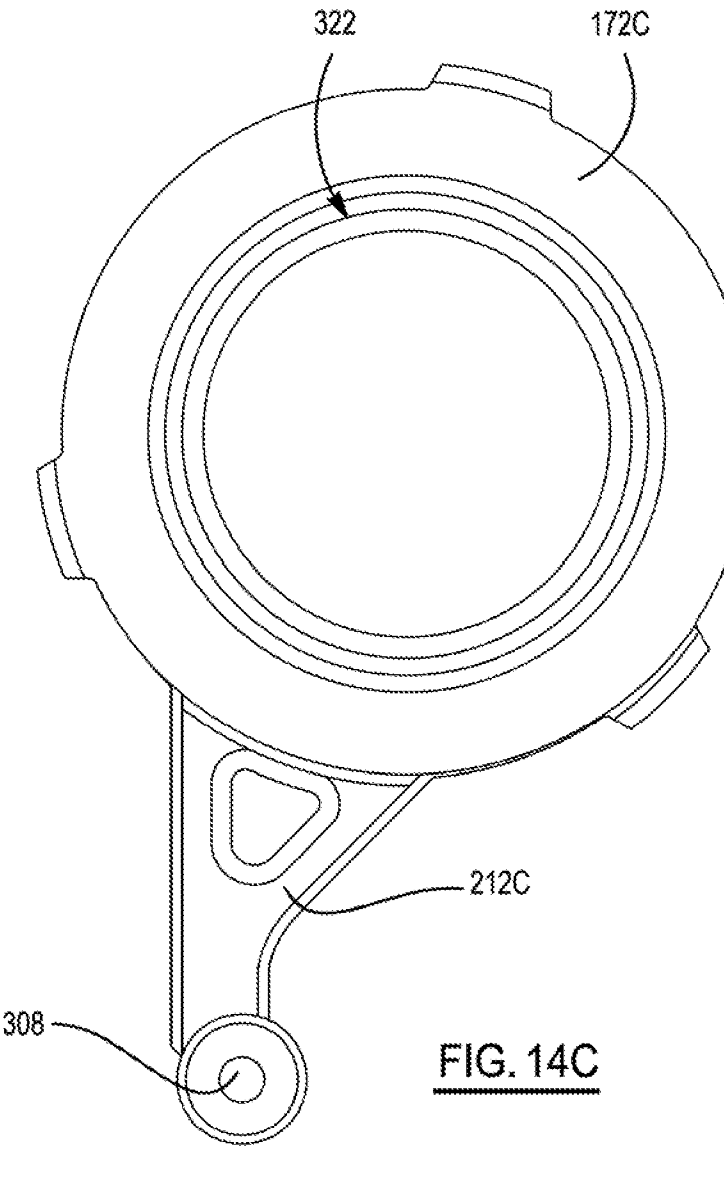

FIG. 14C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/067807

A. CLASSIFICATION OF SUBJECT MATTER
INV. B21J5/12 B60K23/08 F16D23/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21J F16D B21L B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2017/033940 A1 (NTN TOYO BEARING CO LTD [JP]) 2 March 2017 (2017-03-02) figure 5	1-15
Y	EP 2 116 735 A1 (UNIVANCE CORP [JP]) 11 November 2009 (2009-11-11) claim 1; figure 20	1-15
Y	US 2017/326621 A1 (KASHIWAGI ISASHI [JP] ET AL) 16 November 2017 (2017-11-16) paragraph [0043]	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 March 2019	15/03/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Dauvergne, Bertrand

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2018/067807

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 2017033940	A1	02-03-2017	CN	107923449	A	17-04-2018
			DE	112016003863	T5	24-05-2018
			JP	2017044236	A	02-03-2017
			US	2018238402	A1	23-08-2018
			WO	2017033940	A1	02-03-2017
EP 2116735	A1	11-11-2009	CN	101606002	A	16-12-2009
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