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BRAKE ASSEMBLY WITH SPLIT TYPE RACE

Abstract

A brake assembly comprises a rotatable part configured to be rotatable by an actuator and a translatable part operably coupled with the rotatable part and configured to be axially translatable relative to the rotatable part to move the brake pad according to rotation of the rotatable part; and a bearing assembly configured to support the rotatable part. The bearing assembly comprises: an inner race comprising a forward inner race portion and an aft inner race portion; an outer race; and rollable balls. The forward inner race portion located closer to the brake pad than the aft inner race portion is made of a different and/or stronger material from and/or than the aft inner race portion located farther from the brake pad than the forward inner race portion, and/or is smaller than the forward inner race portion located farther from the brake pad than the aft inner race portion.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application claims the benefit from and the priority to U.S. Patent Application Ser. No. 63/553,577, filed on Feb. 14, 2024 entitled “FOUR-POINT BALL BEARING STRUCTURE FOR EMB SYSYEM”, which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] Various embodiments of the present disclosure generally relate to brake assemblies for a vehicle and more particularly to a brake assembly having a bearing assembly with a split type race.

[0003] An electro-mechanical brake (EMB) is a brake assembly that is actuated by electrical energy. For example, the EMB system generally provides braking of a vehicle by the use of a motor which becomes selectively energized in response to a signal of an electronic control unit (ECU) or a sensed depression of a brake input means. Generally, the EMB system may include a rotor, a brake caliper, and brake pads on opposing sides of the rotor. The brake caliper is slideably supported on pins secured to an anchor bracket fixed to a non-rotatable component of the vehicle, and includes one or more piston bores, each of which houses a piston that is movable along a piston axis during a brake apply and release of the brake apply. The brake pads are connected to one or more electrically actuated pistons for movement between a non-braking position and a braking position where the brake pads are moved into frictional engagement with the opposed braking surfaces of the rotor. For example, when an operator of the vehicle depresses a brake pedal, an actuator can move the piston into contact with one brake pad and then move one brake pad into contact with one side of the rotor, while another opposing brake pad is moved into contact with an opposing side of the rotor.

[0004] By way of example and without limitation, such an EMB system provides the desired braking in a substantially shorter amount of time than that which is provided by a conventional hydraulic braking system and allows each of the individual wheels of a vehicle or other selectively movable assembly to be selectively controlled, thereby enhancing the effectiveness of many operating strategies such as an anti-skid or anti-lock braking strategy or a strategy which is commonly referred to as an integrated vehicular dynamic strategy.

SUMMARY

[0005] The features and advantages of the present disclosure will be more readily understood and apparent from the following detailed description, which should be read in conjunction with the accompanying drawings, and from the claims which are appended to the end of the detailed description.

[0006] According to some embodiments of the present disclosure, a brake assembly may comprise: a rotatable part configured to be rotatable by an actuator: a translatable part operably coupled with the rotatable part, the translatable part configured to be axially translatable relative to the rotatable part to move a brake pad according to rotation of the rotatable part; and a bearing assembly configured to support the rotatable part, the bearing assembly comprising: an inner race comprising a forward inner race portion and an aft inner race portion; an outer race; and rollable bodies rollably disposed between the inner race and the outer race.

[0007] The forward inner race portion located closer to the brake pad than the aft inner race portion may have a different material from the aft inner race portion located farther from the brake pad than the forward inner race portion; an outer race.

[0008] The rotatable part may have a protrusion outwardly protruding toward the bearing assembly to form the forward inner race portion located closer to the brake pad than the aft inner race portion such that the forward inner race portion of the inner race is integrally formed on an outside of the rotatable part as a single piece, and the aft inner race portion located farther from the brake pad than the forward inner race portion may be attached to the outside of the rotatable part.

[0009] The forward inner race portion located closer to the brake pad than the aft inner race portion and the aft inner race portion located farther from the brake pad than the forward inner race portion may be shaped asymmetrically to each other.

[0010] The aft inner race portion located farther from the brake pad than the forward inner race portion may be smaller than the forward inner race portion located closer to the brake pad than the aft inner race portion.

[0011] A clearance between the rollable bodies and the aft inner race portion located farther from the brake pad than the forward inner race portion may be greater than a clearance between the rollable bodies and the forward inner race portion located closer to the brake pad than the aft inner race portion.

[0012] The aft inner race portion located farther from the brake pad than the forward inner race portion may have more clearance to the rollable bodies than the outer race and the forward inner race portion located closer to the brake pad than the aft inner race portion.

[0013] A part of the forward inner race portion located closer to the brake pad than the aft inner race portion may be located in a plane passing through centers of the rollable bodies such that a boundary or gap between the forward inner race portion and the aft inner race portion is offset from the plane passing through the centers of the rollable bodies.

[0014] A weight of the aft inner race portion located farther from the brake pad than the forward inner race portion may be lighter than a weight of the forward inner race portion located closer to the brake pad than the aft inner race portion.

[0015] A strength of the aft inner race portion located farther from the brake pad than the forward inner race portion may be lower than a strength of the forward inner race portion located closer to the brake pad than the aft inner race portion.

[0016] An internal radius of curvature of an inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies may be shorter than an internal radius of curvature of an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies.

[0017] A center point of an internal radius of curvature of an inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies may be offset from a center point of an internal radius of curvature of an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies.

[0018] An inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies may be curved, and an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies may be flat.

[0019] The brake assembly may further comprise a retainer configured to support the aft inner race portion, located farther from the brake pad than the forward inner race portion, to limit movement of the aft inner race portion in an axial direction of the rotation part.

[0020] The retainer may extend between a gear or pulley provided on the rotatable body and one side of the aft inner race portion located farther from the brake pad than the forward inner race portion such that the retainer supported by the gear provided on the rotatable body supports the aft inner race portion.

[0021] The brake assembly may further comprise a gear or pulley provided on the rotatable body and supporting one side of the aft inner race portion located farther from the brake pad than the forward inner race portion to retain the aft inner race portion the bearing assembly
[0022] The aft inner race portion located farther from the brake pad than the forward inner race portion may be press-fitted on the rotatable body.
[0023] According to certain embodiments of the present disclosure, a brake assembly may comprise: a brake pad configured to be movable toward or away from a rotor; a nut-screw mechanism configured to move the brake pad, the nut-screw mechanism including a nut part configured to be rotatable and a screw part operably coupled with the nut part and configured to be axially translatable relative to the nut part to move the brake pad according to rotation of the nut part; and a bearing assembly configured to support the nut part, the bearing assembly comprising: an inner race comprising a forward inner race portion and an aft inner race portion; an outer race; and rollable bodies rollably disposed between the inner race and the outer race.
[0024] The forward inner race portion located closer to the brake pad than the aft inner race portion may have a different material from the aft inner race portion located farther from the brake pad than the forward inner race portion.
[0025] A strength of the aft inner race portion located farther from the brake pad than the forward inner race portion may be lower in strength of the forward inner race portion located closer to the brake pad than the aft inner race portion.
[0026] The aft inner race portion located farther from the brake pad than the forward inner race portion may be smaller than the forward inner race portion located closer to the brake pad than the aft inner race portion.
[0027] The nut part may have a protrusion outwardly protruding toward the bearing assembly to form the forward inner race portion located closer to the brake pad than the aft inner race portion such that the forward inner race portion of the inner race is integrally formed on an outside of the nut part as a single piece, and the aft inner race portion located farther from the brake pad than the forward inner race portion may be attached to the outside of the nut part.
[0028] The forward inner race portion located closer to the brake pad than the aft inner race portion and the aft inner race portion located farther from the brake pad than the forward inner race portion may be shaped asymmetrically to each other.
[0029] The aft inner race portion located farther from the brake pad than the forward inner race portion may be smaller than the forward inner race portion located closer to the brake pad than the aft inner race portion.
[0030] A clearance between the rollable bodies and the aft inner race portion located farther from the brake pad than the forward inner race portion may be greater than a clearance between the rollable bodies and the forward inner race portion located closer to the brake pad than the aft inner race portion.
[0031] A part of the forward inner race portion located closer to the brake pad than the aft inner race portion may be located in a plane passing through centers of the rollable bodies such that a boundary or gap between the forward inner race portion and the aft inner race portion is offset from the plane passing through the centers of the rollable bodies.
[0032] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Various embodiments in accordance with the present disclosure will be described with reference to the drawings, in which:

[0034] FIG. **1** is a schematic cross-sectional view of an electro-mechanical brake system according to an embodiment of the present disclosure;

[0035] FIG. **2** is an enlarged view of a bearing assembly taken from a portion A in FIG. **1** according to an embodiment of the present disclosure;

[0036] FIG. **3** is an enlarged view of a bearing assembly taken from a portion B in FIG. **2** according to an embodiment of the present disclosure;

[0037] FIG. **4** is an enlarged view of a bearing assembly taken from a portion A in FIG. **1** according to another embodiment of the present disclosure;

[0038] FIG. **5**A shows a pure axial load path generated in a brake assembly during actuation of an actuator assembly according to an embodiment of the present disclosure;

[0039] FIG. **5**B illustrates a pure radial load path generated in a brake assembly during actuation of an actuator assembly according to an embodiment of the present disclosure;

[0040] FIG. **5**C shows a load path of combination of an axial load and a radial load generated in a bearing assembly included in a brake assembly according to an embodiment of the present disclosure;

[0041] FIG. **6**A to **6**C show a process of assembling a bearing assembly and a rotatable part of a nut-screw mechanism; and

[0042] FIG. **7** illustrates a partial cross-sectional view of an electro-mechanical brake system according to another embodiment of the present disclosure.

[0043] Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated. The figures are drawn to clearly illustrate the relevant aspects of the embodiments and are not necessarily drawn to scale.

DETAILED DESCRIPTION OF EMBODIMENTS

[0044] In the following detailed description, reference is made to the accompanying drawings which form a part of the present disclosure, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that structural, logical and electrical changes may be made without departing from the spirit and scope of the invention. The following detailed description is therefore not to be taken in a limiting sense, and the scope of the invention is defined only by the appended claims and equivalents thereof. Like numbers in the figures refer to like components, which should be apparent from the context of use.

[0045] FIG. **1** is a schematic cross-sectional view of an electro-mechanical brake system according to an embodiment of the present disclosure.

[0046] Referring to FIG. **1**, an electro-mechanical brake (EMB) system **10** may include a brake caliper **110** mounted in a floating manner by means of a brake carrier. When a vehicle is in motion, a brake rotor **125** may rotate with a wheel about an axle of the vehicle. Brake pad assemblies (or brake lining assemblies) **120** are provided in the brake caliper **110**. The brake caliper **110** may include a bridge with fingers, and the fingers of the brake caliper **110** may be in contact with the brake pad assemblies **120**. The brake pad assembly **120** is disposed with a small air clearance on a side of the brake rotor **125**, such as a brake disc, in a release position so that no significant residual drag moment occurs.

[0047] The electro-mechanical brake system **10** may comprise a drive mechanism **200** (such as a nut-screw mechanism and a ball nut-screw mechanism) configured to convert rotary motion generated by an actuator assembly **500** into linear motion in order to move the brake pad assembly **120** toward or away from the brake rotor **125** in an axial direction. The drive mechanism **200** may include a rotatable part **210** and a translatable part **240**. For example, the rotatable part **210** may comprise a nut or a ball nut and the translatable part **240** may comprise a screw or a ball screw, although not required. The nut-screw mechanism **200** may be contained within a housing **600**. The rotatable part **210** and the translatable part **240** may be concentrically mounted in a cavity formed by an inner wall of the housing **600**. The housing **600** may be fixedly coupled with the brake caliper **110**. The rotatable part **210** is operably coupled to the actuator assembly **500**, and is configured to be rotatable by the actuation of the actuator assembly **500**.

[0048] The actuator assembly **500** may comprises an electric motor **520**. For example, the electric motor **520** may be directly engaged with the rotatably part **210** of the drive mechanism **200**. Alternatively, as shown in FIG. **1**, the electric motor **520** may be indirectly connected to the rotatably part **210** through means for transferring rotary force generated by the electric motor **520**, such as one or more gears, one or more belts, one or more pulleys, any other connecting means and combination thereof.

[0049] The actuator assembly **500** may have a multi-stage drive mechanism **540**, although not required. The multi-stage drive mechanism **540** may be implemented as, for example, but not limited to, a dual-stage drive mechanism comprising a belt drive mechanism **541** and a gear drive mechanism **546** to multiply torque from the electric motor **520** to supply rotary force to the rotatable body **210** of the drive mechanism **200**. The belt drive mechanism **541** multiplies the torque from the electric motor **520** by using a motor shaft **522**, a drive pully **524** and a driven pulley **543** rotatably connected by a drive belt **542**, and the torque multiplied by the belt drive mechanism **541** is delivered to the gear drive mechanism **546** through an intermediate shaft **545**. The intermediate shaft **545** may connect the driven pulley **543** of the belt drive mechanism **541** to a first gear **548** of the gear drive mechanism **546** in order to deliver rotary torque, generated by the motor **520** and transmitted through the belt drive mechanism **541**, to the gear drive mechanism **546**. The first gear **548** is rotatably engaged with the second gear **549** to rotate the second gear **549** by the rotary torque transmitted through the intermediate shaft **545**. The second gear **549** may be formed directly on a part of the circumferential surface of the rotatable body or nut **210** of the drive mechanism or screw-nut mechanism **200**, or be mounted to the rotatable body **210** of the drive mechanism **200** to rotate the rotatable body or nut **210**.

[0050] A controller **700** may be configured to control the actuator assembly **500** and a parking lock mechanism **560** configured to lock the movement of a component of the electro-mechanical brake **10** such as a gear, a pulley, a shaft, a nut, and the like by being mechanically interlocked with at least one of components of the electro-mechanical brake system **10**. For example, in a parking lock state, the strut or pin of the parking lock mechanism **560** may be inserted into one of teeth formed on one surface of the driven pulley **543** facing the parking lock mechanism **560**. The controller **700** controls the electric motor **520** to perform a service brake operation and a parking brake operation such as application or release of a service brake and a parking brake. The controller **700** may be, for example, but not limited to, a micro-controller unit (MCU), a circuit chip, a semiconductor circuit, and a circuit board having memory, one or more processors, and electric components. Further, the controller **700** may be configured to communicate with other controllers such as a central electronic control unit (ECU). Therefore, according to the control of the controller **700**, the actuator assembly **500** can provide rotary torque to the nut-screw mechanism **200** to move the brake pad assembly **120** in the brake apply direction or the brake release direction.

[0051] The actuator assembly **500** rotates the rotatable part **210** of the nut-screw mechanism **200**, and then the nut-screw mechanism **200** converts the rotary motion of the rotatable part **210** to the linear motion of the translatable part **240** to move the brake pad assembly **120** between its brake apply and release positions. For example, the actuation of the actuator **500** causes the rotatable part **210** to rotate, and the rotation of the rotatable part **210** causes the translatable part **240** to be linearly moved. Specifically, the rotatable part **210** can rotate relative to the housing **600**, and the rotation of the rotatable part **210** relative to the housing **600** causes to the translatable part **240** advance or retract axially depending on a direction of rotation of the rotatable part **210**. As the rotatable part **210** rotates in an expanding direction, the translatable part **240** linearly translates with respect to the rotatable part **210** and the housing **600** so that the translatable part **240** can translate out from the rotatable part **210** and the housing **600** towards the brake rotor **125**. As the rotatable part **210** rotates in a collapsing direction, the translatable part **240** linearly translates with respect to the rotatable part **210** and the housing **600** so that the translatable part **240** can linearly move toward the rotatable part **210** and the housing **600** in a direction away from the brake rotor **125**. The brake pad footing **205** is fixedly coupled to the translatable part **240** so that the brake pad footing **205** can be linearly movable together with the translatable part **240**. When the nut-screw mechanism **200** is in the expanded state, the brake pad footing **205** pushes the brake pad assembly **120** toward the brake rotor **125**. When the ball-screw mechanism **200** is in the collapsed state, the brake pad footing **205** moves away from the brake rotor **125**.

[0052] While the expanding or collapsing direction depends upon whether the nut or ball nut of the rotatable part **210** and the screw or ball screw of the translatable part **240** are left-handed or right-handed, a specific direction is not critical to some embodiments of the present disclosure, and most embodiments of the present disclosure can work with either.

[0053] The rotatable part **210** may have a tubular shape with axially open ends, and the translatable part **240** is received within an inside space of the rotatable part **210**. The rotatable part **210** and the translatable part **240** are operably connected to each other such that while the rotatable part **210** rotates, the translatable part **240** is linearly movable relative to the rotatable part **210**. In other words, the translatable part **240** is slidable with respect to the rotatable part **210**, but the translatable part **240** cannot be rotatable relative to the rotatable part **210**, and therefore as the rotatable part **210** rotates, the translatable part **240** is linearly moved. For example, the translatable part **240** has a structure configured to prevent the translatable part **240** from rotating relative to the rotatable part **210** while allowing the translatable part **240** to translate in the axial direction.

[0054] At least a part of the translatable part **240** is retained within the rotatable part **210**. The rotatable part **210** has an internally-threaded track groove and the translatable part **240** has an externally-threaded track groove for a rollable body arrangement of rollable bodies **220** (e.g. balls). The rollable bodies **220** are disposed between the internally-threaded track groove of the rotatable part **210** and the externally-threaded track groove of the translatable part **240**. Ball returns either internally or externally carry the rollable bodies **220** from the end of their path back to the beginning to complete their recirculating track. A return tube can perform recirculation of the rollable bodies **220**. The internally-threaded track groove of the rotatable part **210** and the externally-threaded track groove of the translatable part **240** form a series of ball tracks to provide a helical raceway for reception of a train of recirculating the rollable bodies **220**. The rollable bodies **220** may be metal spheres which decrease friction and transfer loads between adjacent components. The rotatable part **210** is rotatably supported by the translatable part **240** via the rollable bodies **220** and a bearing assembly **400**. However, in alternative embodiments of the present disclosure, the rotatable part **210** and the translatable part **240** can be directly engaged with each other without the rollable bodies **220**.

[0055] The bearing assembly **400** is configured to rotatably support the drive mechanism **200** such as a nut-screw mechanism. The bearing assembly **400** may be positioned between the rotatable part **210** of the drive mechanism **200** and a non-rotating structure, for example, but not limited to, the housing **600**. The bearing assembly **400** is used to rotatably support the rotatable part **210** for rotation relative to a non-rotating structure of the brake assembly **10**.

[0056] The bearing assembly **400** may have an inner race **410**, an outer race (or an outer ring) **420**, a plurality of rollable bodies **430** (e.g., bearing balls), and a bearing cage **440**. The bearing assembly **400** may include any number of rollable bodies **430**, for example, more than two balls. The outer race **420** may be located concentrically about the inner race **410**, with the rollable bodies **430** therebetween, in a plane generally perpendicular to a rotatable axis of the rotatable part **210** or the inner race **410** or a translatable axis of the translatable part **240**. The inner race **410** is rotatable, but the outer race **420** is substantially non-rotatable.

[0057] The rollable bodies **430** are configured to aid in rotation of the inner race **410**, formed on and/or coupled to the rotatable part **210**, relative to the outer race (or the outer ring) **420**. The rollable bodies **430** are disposed in an annular cavity, defined by the inner race **410** and the outer race **420**, between the inner race **410** and the outer race **420**. The rollable bodies **430** are supported within the bearing cage **440** such that the rollable bodies **430** are appropriately circumferentially spaced and retained by the bearing cage **440**. The bearing cage **440** is disposed between the inner race **410** and the outer race **420**. In an exemplary embodiment, the rollable bodies **430** may be spherical in shape, for example, but not limited to, balls.

[0058] The inner race **410** defines an inner circumferential surface of the bearing assembly **400**, and is provided on the outside of the rotatable part **210** (e.g. a ball nut of the ball-screw mechanism **200**).

[0059] In an embodiment of the present disclosure, the inner race **410** has a split race configuration such that the inner race **410** includes a forward inner race portion **411** and an aft inner race portion **412**. The forward inner race portion **411** is located closer to the brake pad assembly **120** than the aft inner race portion **412**. The aft inner race portion **412** is located farther from the brake pad assembly **120** than the forward inner race portion **411**.

[0060] The forward inner race portion **411** positioned closer to the brake pad assembly **120** may be directly formed on the outer surface of the rotatable part **210** of the nut-screw mechanism **200**. For example, as illustrated in FIGS. **1** and **2**, a portion of the outer surface of the rotatable part **210** defines the forward inner race portion **411**. More specifically, the rotatable part **210** has a protrusion outwardly projecting toward the bearing assembly **400** to form the forward inner race portion **411**. Therefore, the forward inner race portion **411** can be integrated with the rotatable part **210** as one single piece, thereby providing a simpler assembly process and reducing manufacturing cost. Alternatively, the forward inner race portion **411** may be coupled to the outer surface of the rotatable **210** as a separate piece.

[0061] The aft inner race portion **412** positioned farther from the brake pad assembly **120** may be fixedly attached to the rotatable part **210**. For instance, the aft inner race portion **412** may be coupled to the outer surface of the rotatable part **210** by press-fit or heat drop.

[0062] During the assembly of the bearing assembly **400**, as illustrated in FIG. **6**A the rotatable part **210** of the drive mechanism **200** on which the forward inner race portion **411** is formed is inserted into the center of the outer ring **420** to which the rollable bodies **430** are assembled, and as illustrated in FIGS. **6**B and **6**C the aft inner race portion **412** is inserted to the bearing assembly **400** to be coupled to the rotatable part **210** of the drive mechanism **200**.

[0063] Alternatively, the aft inner race portion **412** may be fixed in place on the outside of the rotatable part **210** using a retainer **490**. The retainer **490** may be utilized as a stopper for the aft inner race portion **412**. As illustrated in FIG. **7**, the retainer **490** may be supported by the second gear **549** attached to the rotatable part **210** such that the retainer **490** can limit the axial movement of the aft inner race portion **412** and the aft inner race portion **412** can be securely fixed in position by being supported by the retainer **490**. As another example, a groove may be formed on the outer surface of the rotatable part **210** around one side of the aft inner race portion **412**, and the retainer **490** such as a snap-type ring (e.g. a generally C-shaped retaining ring) may be removably seated within the groove of the rotatable part **210** so that the retainer **490** can support one side of the aft inner race portion **412** or provide an axial stop for the aft inner race portion **412**. Alternatively, a part of a gear or pulley (e.g. the second gear **549**) provided on the outer surface of the rotatable part **210** can extend to the aft inner race portion **412** to support one side of the aft inner race portion **412** such that the part of a gear or pulley provided on the outer surface of the rotatable part **210** can function as a stopper instead of including the retainer **490** as a separate piece. For instance, the retainer **490** may be integrated into the gear or pulley provided on the outer surface of the rotatable part **210**.

[0064] In FIG. **5**A showing a pure axial load path in the brake assembly **10** according to an embodiment of the present disclosure, the actuation of the actuator assembly **500** generates a compression load on the translatable part **230** (e.g. a ball screw). The compression load on the translatable part **230** can be transmitted to the rotatable part **210** through the rollable bodies **430**. A first action arrow **612** shows an axial load which is caused by a force transferred to the rotatable part **210** (e.g. a ball nut) via the rollable bodies **261** (e.g. internal ball nut/screw balls). Then, the force transferred to the rotatable part **210** acts on the bearing assembly **400**. The force transferred through the bearing assembly **400** creates a load supporting line **613**, thereby forming two contact points per rollable body **430** because the inner race **410** and the outer race **420** move in opposite axial directions relative to each other. One contact point **616** per rollable body **430** is formed on the forward inner race portion **411**, and another contact point **617** per rollable body **430** is formed on the outer race **420**. Accordingly, among the forward inner race portion **411** and the aft inner race portion **412** included in the inner race **410**, one contact point per rollable body **430** is formed at the forward inner race portion **411** only. The force on the bearing assembly **400** is transferred to a part of the housing **600**. A second action arrow **614** illustrates a force transferred from the outer race **232** of the bearing assembly **230** to a part of the housing **600** (e.g. an EMB bridge) in an axial direction.

[0065] In FIG. **5**B showing a pure radial load path in the brake assembly **10** according to an embodiment of the present disclosure, the actuation of the actuator assembly **500** places a relatively small radial load on the translatable part **230** (e.g. a ball screw). The radial load on the translatable part **230** can be transmitted to the rotatable part **210** through the rollable bodies **430**. A first action arrow **622** shows a radial load which is caused by a force transferred to the rotatable part **210** (e.g. a ball nut) via the rollable bodies **430** (e.g. internal ball nut/screw balls). Then, the force transferred to the rotatable part **210** acts on the bearing assembly **400**. A force transferred through the bearing assembly **400** creates two load supporting lines **623**, **624**, thereby forming four contact points per rollable body **430** since the inner race **410** and the outer race **420** radially move toward each other. The first load supporting line **623** can form a first contact point **631** on the forward inner race portion **411**, and a second contact point **632** on a portion of the outer race **420**. The second load supporting line **624** can form a third contact point **633** on the aft inner race portion **412**, and a fourth contact point **634** on the outer race **420**. Therefore, two contact points are formed at each of the inner race **410** and the outer race **420** per rollable body **430**. The force on the bearing assembly **400** is transferred to a part of the housing **600**. A second action line **625** illustrates a force transferred from the outer race **420** of the bearing assembly **400** to a part of the housing **600** (e.g. an EMB bridge) in a radial direction.

[0066] FIG. **5**C shows a load path of combination of the axial load and the radial load generated in the brake assembly **10** according to an embodiment of the present disclosure. As illustrated in FIGS. **6**A and **6**B, a relatively large axial load vector is generated by the actuation of the actuator assembly **500** during the brake apply, while a radial load vector relatively much smaller than the axial load vector is generated. The deflection of the brake caliper **110** during a braking event may be the source of the radial load. The combination of the large axial load vector and the small radial load vector can create one load supporting line **643** forming two contact points **647** and **648** per rollable body **430** in the bearing assembly **400**. One contact point **647** of the combination load is formed on the forward inner race portion **411** while no contact point is formed on the aft inner race portion **412**, and another contact point **648** is formed on the outer race **420**. Accordingly, the forward inner race portion **411** can act as a high load-bearing inner race portion on which loads are applied, while the aft inner race portion **412** can act as a non-load-bearing inner race portion during a braking event. Among the forward inner race portion **411** and the aft inner race portion **412** included in the inner race **410**, the forward inner race portion **411** on which a contact point per rollable body **430** is formed endures high axial loads. Unlike the forward inner race portion **411**, the aft inner race portion **412** does not need to endure the load generated during the brake operation of the brake assembly **10**, and can function only for retaining the rollable bodies **430** and preventing the disassembly of the bearing assembly **400**.

[0067] Therefore, according to some embodiments of the present disclosure, the forward inner race portion **411** and the aft inner race portion **412** of the inner race **410** may be made of different materials and have different shapes, respectively, and/or be configured differently from each other.

[0068] Because no or relatively small load is applied to the aft inner race portion **412** during the brake operation of the brake assembly **10** and the aft inner race portion **412** only performs the function of retaining the rollable bodies **430** and preventing the disassembly of the bearing assembly **400**, the aft inner race portion **412** may have less material than the forward inner race portion **411**, and the aft inner race portion **412** may be made of a material of lower strength and/or less weight than the forward inner race portion **411**.

[0069] Low-cost material, for example, but not limited to, such as steel without heat treatment, aluminum, plastic, and the like can be used for the aft inner race portion **412** without affecting the performance of the bearing assembly **400** during the brake operation of the brake assembly **10**, thereby reducing the cost for manufacturing the bearing assembly **400**.

[0070] In addition, by making the aft inner race portion **412** lighter in weight, the overall weight of the bearing assembly **420** can be lowered without affecting the capability of the inner race **410** which can endure the load generated during the braking operation of the brake assembly **10**.

[0071] The forward inner race portion **411** and the aft inner race portion **412** may have a different shape from each other. The forward inner race portion **411** and the aft inner race portion **412** may be asymmetrical about an axis of the rollable body **430**.

[0072] For example, the aft inner race portion **412** may be smaller than the forward inner race portion **411**. The reduction in the size of the aft inner race portion **412** may not affect the function of the bearing assembly **400** which supports the load generated when the brake operation of the brake assembly **10** is being performed. Accordingly, less material can be used for the aft inner race portion **412**, and the size of the aft inner race portion **412** can be made smaller without degrading the performance of bearing assembly **400** for the brake operation of the brake assembly **10**.

[0073] A part of the forward inner race portion **411** may be located in a plane perpendicular to the rotatable axis of the rotatable part **210** and/or passing through centers of the rollable bodies **430** such that the boundary or gap formed between the forward inner race portion **411** and the aft inner race portion **412** is offset from the plane perpendicular to the rotatable axis of the rotatable part **210** and/or passing through the centers of the rollable bodies **430**.

[0074] Because the reduction in the size of the aft inner race portion **412** and the center offset of the forward inner race portion **411**, the overall length and/or diameter of the bearing assembly can make shorter than a conventional Conrad type bearing while maintaining the capability to withstand the high load generated by the brake operation. In addition, in split design and configuration of the inner race **410** comprising the forward inner race portion **411** and the aft inner race portion **412** described above, the bearing assembly **400** can carry more rollable bodies **430** (e.g. balls) between the split type inner race **410** and the outer race **420** in comparison to a conventional Conrad type bearing having the lower limit to the number of balls, thereby providing higher load carrying capability.

[0075] In the bearing configuration shown in FIG. **2**, the aft inner race portion **412** may have more clearance to the rollable bodies **430** than the forward inner race portion **411** and/or the outer race **420** in an unloaded state. The internal radius of curvature of the concave spherical surface of the forward inner race portion **411** is shorter than the internal radius of curvature of the concave spherical surface of the aft inner race portion **412**, thereby producing a first gap between the outer surface of the rollable body **430** and the concave spherical surface of the forward inner race portion **411** that is smaller than a second gap between the outer surface of the rollable body **430** and the concave spherical surface of the aft inner race portion **412**. The center point of the internal radius of curvature of the concave spherical surface of the forward inner race portion **411** may also be axially and/or radially offset in space from the center point of the internal radius of curvature of the concave spherical surface of the aft inner race portion **412**, thereby aligning the first gap between the outer surface of the rollable body **430** and the concave spherical surface of the forward inner race portion **411** differently than the second gap between the outer surface of the rollable body **430** and the concave spherical surface of the aft inner race portion **412** to allow for asymmetric loading and contact stress characteristics between the rollable bodies **430** and the inner surfaces of the forward inner race portion **411**, the forward inner race portion **412**, and the outer race **420**.

[0076] Therefore, according to certain embodiments of the present disclosure, by the center offset of the forward inner race portion **411** and the aft inner race portion **412** and the difference of a first clearance between the forward inner race portion **411** and the rollable body **430** and a second clearance between the aft inner race portion **412** and the rollable body **430**, the rollable bodies **430** may mainly contact the forward inner race portion **411** under no load condition to provide optimal performance of the bearing assembly **400**.

[0077] Alternatively, the inner surface of the aft inner race portion **412** facing the rollable bodies **430** may be formed as a flat surface **443** or an incline groove as illustrated in FIG. **4** for the use of simper shape configurations to reduce the manufacturing cost and simplify the process of the manufacturing the bearing assembly **400**.

[0078] According to certain embodiments of the present disclosure, due to the asymmetric race profiles of the inner surfaces of the forward inner race portion **411** and the aft inner race portion **412**, radial and axial load capacity in one axial direction can be achieved in the forward inner race portion **411** even though the overall size and weight of the bearing assembly **400** are reduced.

[0079] According to some embodiments of the present disclosure, a more cost effective or cheaper material and simpler design or shape configuration can be used for the aft inner race portion **412** than the forward inner race portion **411** without affecting the performance of the bearing assembly **400**.

[0080] According to certain embodiments of the present disclosure, the process for ring matching requiring high cost is not needed because the aft inner race portion **412** has the only function of retaining the rollable bodies **430** and preventing the disassembly of the bearing assembly **400**. While the bearing assembly **400** is being assembled, a manufacturer requires to control radial lash of the bearing assembly **400** before the aft inner race portion **412** is coupled to the bearing assembly **400**. Once the aft inner race portion **412** is assembled to the bearing assembly **400**, the bearing assembly **400** including the aft inner race portion **412** according to certain embodiments of the present disclosure may not reduce the radial lash within the bearing assembly **400**, and therefore the ring matching process for the bearing assembly **400** according to certain embodiments of the present disclosure may not be needed. Hence, less precision production methods for the bearing assembly **400** can be used by having a split race configuration of an inner race including the forward inner race portion **411** and the aft inner race portion **412** described above.

[0081] Although the outer race **420** is illustrated as a single piece race in certain embodiments of the present disclosure, the outer race **420** may has a split race configuration such that the outer race **420** includes a forward outer race portion and an aft outer race portion. However, the forward outer race portion of the outer race **420** may be implemented with the explanation regarding the aft inner race portion **412** described above and the aft outer race portion of the outer race **420** may be implemented with the explanation about the forward inner race portion **411** described above.

[0082] Although the example embodiments have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the present disclosure as defined by the appended claims.

[0083] Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, and composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure, processes, machines, manufacture, compositions of matter, means, methods or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the embodiments and alternative embodiments. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

[0084] The explanations and illustrations presented herein are intended to acquaint others skilled in the art with the invention, its principles, and its practical application. The above description is intended to be illustrative and not restrictive. Those skilled in the art may adapt and apply the invention in its numerous forms, as may be best suited to the requirements of a particular use.

[0085] Accordingly, the specific embodiments of the present invention as set forth are not intended as being exhaustive or limiting of the teachings. The scope of the teachings should, therefore, be determined not with reference to this description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. The omission in the following claims of any aspect of subject matter that is disclosed herein is not a disclaimer of such subject matter, nor should it be regarded that the inventors did not consider such subject matter to be part of the disclosed inventive subject matter.

[0086] Plural elements or steps can be provided by a single integrated element or step. Alternatively, a single element or step might be divided into separate plural elements or steps.

[0087] The disclosure of “a” or “one” to describe an element or step is not intended to foreclose additional elements or steps.

[0088] While the terms first, second, third, etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings.

[0089] Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

Claims

1. A brake assembly comprising: a rotatable part configured to be rotatable by an actuator; a translatable part operably coupled with the rotatable part, the translatable part configured to be axially translatable relative to the rotatable part to move a brake pad according to rotation of the rotatable part; and a bearing assembly configured to support the rotatable part, the bearing assembly comprising: an inner race comprising a forward inner race portion and an aft inner race portion, wherein the aft inner race portion located farther from the brake pad than the forward inner race portion is smaller than the forward inner race portion located closer to the brake pad than the aft inner race portion; an outer race; and rollable bodies rollably disposed between the inner race and the outer race.

2. The brake assembly of claim 1, wherein; the rotatable part has a protrusion outwardly protruding toward the bearing assembly to form the forward inner race portion located closer to the brake pad than the aft inner race portion such that the forward inner race portion of the inner race is integrally formed on an outside of the rotatable part as a single piece, and the aft inner race portion located farther from the brake pad than the forward inner race portion is attached to the outside of the rotatable part.
3. The brake assembly of claim 1, wherein the forward inner race portion located closer to the brake pad than the aft inner race portion and the aft inner race portion located farther from the brake pad than the forward inner race portion are shaped asymmetrically to each other.
4. The brake assembly of claim 1, wherein a clearance between the rollable bodies and the aft inner race portion located farther from the brake pad than the forward inner race portion is greater than a clearance between the rollable bodies and the forward inner race portion located closer to the brake pad than the aft inner race portion.
5. The brake assembly of claim 1, wherein the aft inner race portion located farther from the brake pad than the forward inner race portion has more clearance to the rollable bodies than the outer race and the forward inner race portion located closer to the brake pad than the aft inner race portion.
6. The brake assembly of claim 1, wherein a part of the forward inner race portion located closer to the brake pad than the aft inner race portion is located in a plane passing through centers of the rollable bodies such that a boundary or gap between the forward inner race portion and the aft inner race portion is offset from the plane passing through the centers of the rollable bodies.
7. The brake assembly of claim 1, wherein the forward inner race portion located closer to the brake pad than the aft inner race portion has a different material from the aft inner race portion located farther from the brake pad than the forward inner race portion.
8. The brake assembly of claim 1, wherein a weight of the aft inner race portion located farther from the brake pad than the forward inner race portion is lighter than a weight of the forward inner race portion located closer to the brake pad than the aft inner race portion.
9. The brake assembly of claim 1, wherein a strength of the aft inner race portion located farther from the brake pad than the forward inner race portion is lower in strength of the forward inner race portion located closer to the brake pad than the aft inner race portion.
10. The brake assembly of claim 1, wherein an internal radius of curvature of an inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies is shorter than an internal radius of curvature of an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies.
11. The brake assembly of claim 1, wherein a center point of an internal radius of curvature of an inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies is offset from a center point of an internal radius of curvature of an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies.
12. The brake assembly of claim 1, wherein: an inner surface of the forward inner race portion, located closer to the brake pad than the aft inner race portion, facing the rollable bodies is curved, and an inner surface of the aft inner race portion, located farther from the brake pad than the forward inner race portion, facing the rollable bodies is flat.
13. The brake assembly of claim 1, further comprising a retainer configured to support the aft inner race portion, located farther from the brake pad than the forward inner race portion, to limit movement of the aft inner race portion in an axial direction of the rotation part.
14. The brake assembly of claim 13, wherein the retainer extends between a gear or pulley provided on the rotatable body and one side of the aft inner race portion located farther from the brake pad than the forward inner race portion such that the retainer supported by the gear provided on the rotatable body supports the aft inner race portion.

15. The brake assembly of claim 1, further comprising a gear or pulley provided on the rotatable body and supporting one side of the aft inner race portion located farther from the brake pad than the forward inner race portion to retain the aft inner race portion the bearing assembly.
16. The brake assembly of claim 1, wherein the aft inner race portion located farther from the brake pad than the forward inner race portion is press-fitted on the rotatable body.
17. A brake assembly comprising: a rotatable part configured to be rotatable by an actuator; a translatable part operably coupled with the rotatable part, the translatable part configured to be axially translatable relative to the rotatable part to move a brake pad according to rotation of the rotatable part; and a bearing assembly configured to support the rotatable part, the bearing assembly comprising: an inner race comprising a forward inner race portion and an aft inner race portion, wherein the forward inner race portion located closer to the brake pad than the aft inner race portion has a different material from the aft inner race portion located farther from the brake pad than the forward inner race portion; an outer race; and rollable bodies rollably disposed between the inner race and the outer race.
18. The brake assembly of claim 17, wherein a strength of the aft inner race portion located farther from the brake pad than the forward inner race portion is lower in strength of the forward inner race portion located closer to the brake pad than the aft inner race portion.
19. A brake assembly comprising: a rotatable part configured to be rotatable by an actuator; a translatable part operably coupled with the rotatable part, the translatable part configured to be axially translatable relative to the rotatable part to move a brake pad according to rotation of the rotatable part; and a bearing assembly configured to support the rotatable part, the bearing assembly comprising: an inner race comprising a forward inner race portion and an aft inner race portion, wherein a strength of the aft inner race portion located farther from the brake pad than the forward inner race portion is lower in strength of the forward inner race portion located closer to the brake pad than the aft inner race portion; an outer race; and rollable bodies rollably disposed between the inner race and the outer race.
20. The brake assembly of claim 19, wherein the aft inner race portion located farther from the brake pad than the forward inter race portion is smaller than the forward inner race portion located closer to the brake pad than the aft inner race portion.