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[Continued on next page]

(54) Title: ASYMMETRIC BEARING WITH FAIL SAFE TAB

(57) Abstract: Crankshaft thrust bearings for an internal combustion engine are provided. The crankshaft thrust bearings cooperate to form asymmetric full round axial bearings which integrate fail safe tabs to avoid incorrect installation within an engine cylinder block and main bearing cap. The thrust bearings include a first asymmetric full round axial bearing uniquely configured to be installed only in the front section of an engine cylinder block and main bearing cap and a second asymmetric full round axial bearing uniquely configured to be installed only in the rear section of an engine cylinder block and main bearing cap.

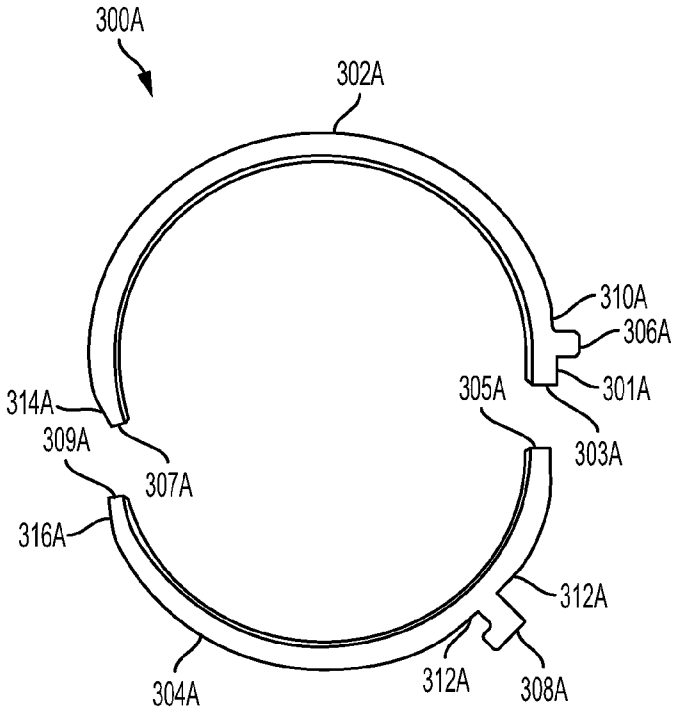

FIG. 3A

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PATENT APPLICATION

of

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for

ASYMMETRIC BEARING WITH FAIL SAFE TAB

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ASYMMETRIC BEARING WITH FAIL SAFE TAB

PRIORITY CLAIM

[0001] This application claims priority to U.S. Provisional Application No. 62/143,740, which is entitled "ASYMMETRIC FULL ROUND AXIAL BEARING WITH FAIL SAFE TAB AND GRAVITY SUPPORT INSTALLATION TABS," and was filed on April 6, 2015, the entire disclosure of which is expressly incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] The present disclosure generally relates to a crankshaft thrust bearing for an internal combustion engine, and more particularly to an asymmetric full round axial bearing which integrates fail safe tabs to avoid incorrect installation.

BACKGROUND OF THE DISCLOSURE

[0003] Thrust bearings may be used for minimizing axial movement of a crankshaft in a transmission of an internal combustion engine. Thrust bearings can be vulnerable to incorrect assembly, potentially resulting in damage occurring during the incorrect assembly and/or during operation of the internal combustion engine. Prior art thrust bearings generally consist of a semi-circular configuration resulting in a design that may be unable to accept higher thrust forces during engine operation. More specifically, prior art thrust bearings are typically bi-directional such that parts associated with the forward thrust bearing and the rear thrust bearing are identical, and part placement and positioning is not dependent on the direction of rotation of the crank shaft. This conventional thrust bearing design approach may result in engine performance that is limited because the bi-directional design is not ideal for internal combustion engines having higher thrust force requirements. Moreover, some prior art uni-directional crankshaft thrust bearings include a design profile that is not adequately fail safe resulting in degraded engine performance due to incorrect thrust bearing installation. As such a need exists for a thrust bearing design that exhibits improved fail safe functionality, such that one or more thrust bearings can reliably accept a crankshaft thrust force of at least 10.9 kilo-Newton (kN).

SUMMARY OF THE DISCLOSURE

[0004] In one embodiment of the present disclosure a bearing assembly is provided comprising, a first bearing comprising a first section having a first arcuate length and a second section having a second arcuate length wherein the first arcuate length is greater than the second arcuate length; a second bearing comprising a third section having a third arcuate length and a fourth section having a fourth arcuate length wherein the third arcuate length is greater than the fourth arcuate length; a first tab disposed on the first section of the first bearing and a second tab disposed on the second section of the first bearing; and a third tab disposed on the third section of the second bearing and a fourth tab disposed on the fourth section of the second bearing. In one aspect of this embodiment, the bearing assembly further comprises a main bearing cap comprising an upper forward end, a lower forward end, an upper rearward end and a lower rearward end, the main bearing cap configured to: receive, in the upper forward end, the first section of the first bearing; receive, in the lower forward end, the second section of the first bearing; receive, in the upper rearward end, the third section of the second bearing; receive, in the lower rearward end, the fourth section of the second bearing.

[0005] In a variant of this aspect, the first tab is disposed on the first section at a first circumferential position and the second tab is disposed on the second section at a second circumferential position that is different from the first circumferential position. In another variant of this aspect, the third tab is disposed on the third section at a first circumferential position and the fourth tab is disposed on the fourth section at a second circumferential position that is different from the first circumferential position. In yet another variant of this aspect, the first section opposes the second section when the first bearing is received by a forward end of the main bearing cap and, wherein the third section opposes the fourth section when the second bearing is received by a rearward end of the main bearing cap.

[0006] In another aspect of this embodiment, the first and second sections each comprise a first end, a second end, a first beveled area disposed toward the first end, and a second beveled area disposed directly adjacent the second end. In a variant of this aspect, the third and fourth sections each comprise a first end and a second end, and wherein the third section comprises a first beveled area disposed adjacent the first end and a second beveled area disposed directly adjacent the second end, and the fourth section comprises a first beveled area disposed directly

adjacent the fourth tab and a second beveled area disposed directly adjacent the second end. In a variant of this variant, the beveled areas of the first and second bearings are structured to mitigate damage to the bearings when the first and second bearings are received by a main bearing cap of an engine.

[0007] In another embodiment of the present disclosure an apparatus is provided, comprising, a first bearing comprising an upper section and a lower section and at least one tab disposed along an outer radial portion of the first bearing, the upper section having arcuate length that is greater than an arcuate length of the lower section; and a second bearing comprising an upper section and a lower section and at least one tab disposed along an outer radial portion of the second bearing, the upper section having arcuate length that is greater than an arcuate length of the lower section; wherein a circumferential location of the at least one tab of the first bearing and the arcuate length of the upper and lower sections of the first bearing are configured to correspond to a forward end of a main bearing cap; and wherein a circumferential location of the at least one tab of the second bearing and the arcuate length of the upper and lower sections of the second bearing are configured to correspond to a rearward end of the main bearing cap.

[0008] In one aspect of this embodiment, an asymmetry in the arcuate length of the upper and lower sections of the first bearing and an asymmetry in the arcuate length of the upper and lower sections of the second bearing distribute thrust loads applied to the first and second bearings during operation of an engine. In another aspect of this embodiment, the upper section of the first bearing comprises a first end and a second end, a first tab disposed adjacent the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end. In a variant of this aspect, the lower section of the first bearing comprises a first end and a second end, a second tab disposed toward the first end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end. In a variant of this variant, the first tab of the first bearing is received within a first cast pocket of the main bearing cap and the second tab of the first bearing is received within a second cast pocket of the main bearing cap.

[0009] In yet another aspect of this embodiment, the upper section of the second bearing comprises a first end and a second end, a first tab disposed at the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end. In a

variant of this aspect, the lower section of the second bearing comprises a first end and a second end, a second tab disposed toward the second end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end. In a variant of this variant, the first tab of the second bearing is received within a third cast pocket of the main bearing cap and the second tab of the second bearing is received within a fourth cast pocket of the main bearing cap.

[00010] In yet another embodiment of the present disclosure an apparatus is provided, comprising, an engine comprising a main bearing cap having a forward end and a rearward end; a first bearing disposed at the forward end, the first bearing comprising at least one tab, an upper section, a lower section, and an asymmetry in an arcuate length of the upper and lower sections; and a second bearing disposed at the rearward end, the second bearing comprising at least one tab, an upper section, a lower section, and an asymmetry in an arcuate length of the upper and lower sections; wherein a circumferential location of the at least one tab of the first bearing and the asymmetry in the arcuate length of the first bearing are configured to correspond to a forward end of the main bearing cap; and wherein a circumferential location of the at least one tab of the second bearing and the asymmetry in the arcuate length of the second bearing are configured to correspond to a forward end of the main bearing cap.

[00011] In one aspect of this embodiment, the asymmetry in the arcuate length of the upper and lower sections of the first bearing and the asymmetry in the arcuate length of the upper and lower sections of the second bearing distribute thrust loads applied to the first and second bearings during operation of the engine. In another aspect of this embodiment, the upper section of the first bearing comprises a first end and a second end, a first tab disposed adjacent the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end. In a variant of this aspect, the lower section of the first bearing comprises a first end and a second end, a second tab disposed toward the first end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end. In yet another aspect of this embodiment, the upper section of the second bearing comprises a first end and a second end, a first tab disposed at the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end. In a variant of this aspect, the lower section of the second bearing comprises a first end and a second end, a

second tab disposed toward the second end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end.

BRIEF DESCRIPTION OF THE DRAWINGS

[00012] The above-mentioned and other features of this disclosure and the manner of obtaining them will become more apparent and the disclosure itself will be better understood by reference to the following description of embodiments of the present disclosure taken in conjunction with the accompanying drawings, wherein:

[00013] FIG. 1A is an exploded view of bearing sections of a front bearing;

[00014] FIG. 1B is an exploded view of bearing sections of a rear bearing;

[00015] FIG. 2A is an assembled front view of the bearing of FIG. 1A;

[00016] FIG. 2B is an assembled front view of the bearing of FIG. 1B;

[00017] FIG. 3A is another exploded view of bearing sections of a front bearing;

[00018] FIG. 3B is another exploded view of bearing sections of a rear bearing;

[00019] FIG. 4A is an assembled front view of the bearing of FIG. 3A;

[00020] FIG. 4B is an assembled front view of the bearing of FIG. 3B;

[00021] FIG. 5A shows the bearing of FIG. 4A installed in the front section of a main bearing cap; and

[00022] FIG. 5B shows the bearing of FIG. 4B installed in the rear section of a main bearing cap.

DETAILED DESCRIPTION OF EMBODIMENTS

[00023] The following description is merely exemplary in nature and is in no way intended to limit the disclosure, its application, or uses. As used herein, the phrase at least one of A, B, or C should be construed to mean a logical (A or B or C), using a non-exclusive logical OR. It should be understood that steps within a method disclosed herein may be executed in a different order without altering the principles of the present disclosure. The embodiments disclosed herein are not intended to be exhaustive or to limit the disclosure to the precise forms

disclosed in the following detailed description. Rather, the embodiments were chosen and described so that others skilled in the art may utilize their teachings.

[00024] FIGs. 1A and 1B show the individual sections of a pair of uni-directional thrust bearings in accordance with the present disclosure. FIG. 1A shows front thrust bearing ("TB") assembly 100A in an unassembled arrangement which includes two distinct sections of TB 100A being spaced apart. TB 100A includes front top TB 102A and front bottom TB 104A. Front top TB 102A includes first end section 103A, tab 106A, second end section 107A, notch or bevel 110A and notch/bevel 114A. Front bottom TB 104A includes third end section 105A, tab 108A, fourth end section 109A, notch/bevel 112A and notch/bevel 116A. The one or more thrust bearings shown in various illustrative embodiments of the present disclosure are designed to be installed within the front section or rear section of a main bearing cap (hereinafter "MBC") of an internal combustion engine. In the illustrative embodiment of FIG. 1A, front top TB 102A and front bottom TB 104A are each structured as an arc having a single connection tab 106A and 108A disposed in the peripheral direction on a radially outer edge of each thrust bearing. Tabs 106A and 108A are directed radially outward such that front top TB 102A and front bottom TB 104A may be coupled to, for example, a MBC of internal combustion engine via at least two cast or machined pockets within the MBC. Each cast or machined pocket may be configured to receive tab 106A and 108A respectively.

[00025] FIG. 1B shows rear thrust bearing ("TB") assembly 100B in an unassembled arrangement which includes two distinct sections of TB 100B being spaced apart. TB 100B includes rear top TB 102B and rear bottom TB 104B. Rear top TB 102B includes first end section 103B, tab 106B, second end section 107B, notch/bevel 110B and notch/bevel 114B. Rear bottom TB 104B includes third end section 105B, tab 108B, fourth end section 109B, notch/bevel 112B and notch/bevel 116B. TB 100B includes a design profile that is substantially similar to TB 100A, except that the position of tab 108B differs substantially from the position of tab 108A, while the position of tab 106A may be substantially similar to or identical to the position of tab 106B.

[00026] Axial thrust bearings may be used, for example, in engine construction as crankshaft bearings or the like. A crankshaft of an internal combustion engine is supported at a journal portion thereof by a lower portion of a cylinder block of the internal combustion engine

via a main bearing constituted of a pair of bearings that are typically semi-cylindrical in design. A first thrust bearing may be positioned at the front section of a MBC of the internal combustion engine while a second thrust bearing may be positioned at the aft or rear section of the MBC. As indicated above, front top TB 102A and front bottom 104A are two distinct sections which combine to form front TB assembly 100A. Likewise, rear top 102B and rear bottom TB 104B are two distinct sections which combine to form rear TB assembly 100B. In various embodiments of the present disclosure, front TB assembly 100A is designed for installation in the front section of a MBC while rear TB assembly 100B is designed for installation in the aft or rear section of a MBC. The individual and distinct sections of TB 100A and TB 100B cooperate to form a pair of uni-directional thrust bearings having a bearing profile that provides partial fail safe functionality. Namely, the distinct arc lining profile and tab placement among each of the four sections of TB 100A (tabs 106A/108A) and TB 100B (tabs 106B/108B) cooperate to provide a pair of asymmetric full round axial bearings that integrate fail safe tabs to avoid incorrect bearing installation within the MBC and cylinder block of an internal combustion engine.

[00027] FIGs. 2A and 2B show the individual sections of FIGs. 1A and 1B which combine to form a pair of uni-directional thrust bearings in accordance with the present disclosure. As shown in the illustrative embodiment of FIGs. 2A and 2B, front TB 200A includes front top TB 102A and front bottom TB 104A which interface or couple at interface location 202A and 204A, likewise rear TB 200B includes rear top TB 102B and rear bottom TB 104B which interface or couple at interface location 202B and 204B. The illustrative embodiment of FIGs. 2A and 2B provide a pair of asymmetric full round axial thrust bearings (front and rear) that allow for correct installation within a MBC. However, while the arc profile design of thrust bearings 200A/B provides some fail safe installation functionality, the design does not provide substantial mitigation against incorrect installation within a MBC of an engine.

[00028] The asymmetric full round axial bearings of FIGs. 2A and 2B are generally defined by four distinct bearing sections and each bearing section has a unique sweep angle. Front TB assembly 200A includes a design profile that is substantially similar to rear TB assembly 200B. In one embodiment, although the radial location of tab 108A may differ substantially from the radial location of tab 108B, the radial location of tab 106A may be the same as (or substantially similar to) the radial location of tab 106B. Additionally, in one

embodiment, front top TB 102A includes an arc profile having a sweep angle that exceeds 180° relative to the X-axis. Likewise, rear top TB 102B may include an arc profile having a sweep angle that also exceeds 180° relative to the X-axis. In one embodiment, rear top TB 102B includes an arc profile having a sweep angle that slightly exceeds the sweep angle of front top TB 102A. Accordingly, because front top TB 102A and rear top TB 102B may each have the same radial tab locations and only marginally distinguishable sweep angles, the pair of uni-directional thrust bearings illustratively disclosed in FIGs. 2A and 2B do not provide complete or substantial fail safe installation functionality. For example, in an alternative embodiment, the marginal difference in sweep angles could result in rear top TB 102B being installed in the section of the MBC configured to receive front top TB 102A. This may result in degraded engine performance due to the incorrect thrust bearing installation.

[00029] FIGs. 3A and 3B show another pair of uni-directional thrust bearings, front TB assembly 300A and rear TB assembly 300B, in an exemplary embodiment of the present disclosure. Front TB 300A generally includes two distinct sections, namely, top TB 302A having tab 306A and bottom TB 304A having tab 308A. Likewise, rear TB 300B generally includes two distinct sections, namely, top TB 302B and bottom TB 304B. The two distinct sections of front TB 300A and rear TB 300B have an arc lining profile and tab location that is substantially the same as the distinct sections of front TB 100A and rear TB 100B except that front TB 300A includes a tab 306A positioned at a radial location that is distinguishable from the radial location of tab 106A. Accordingly, the illustrative embodiment of FIGs. 3A and 3B provide a pair of asymmetric full round axial thrust bearing that allows for correct installation and provides complete or substantial fail safe functionality due, in part, to the asymmetrical sweep used to distribute thrust loads applied to the bearings during operation of an internal combustion engine. The asymmetric full round axial bearings of FIGs. 3A and 3B are defined by four distinct bearing sections wherein each bearing section has a unique sweep angle that provides for optimal or balanced load distribution during crankshaft revolutions. As described in more detail in the illustrative embodiments of FIGs. 5A and 5B, each section of front TB 300A and rear TB 300B is capable of mechanical coupling to the MBC of an engine. Moreover, front bottom TB 304A along with rear bottom TB 304B each include coupling tabs 308A and 308B that allow for ease of installation due to gravity allowing each bottom thrust bearing to remain coupled to the MBC when the MBC is in an inverted orientation.

[00030] In the illustrative embodiment of FIG. 3A, front TB 300A includes a first end section 303A, a second end section 305A, a third end section 307A and a fourth end section 309A. Likewise, in the illustrative embodiment of FIG. 3B, rear TB 300B includes a first end section 303B, a second end section 305B, a third end section 307B and a fourth end section 309B. Front top TB 302A also includes an arc profile having a single connection tab 306A disposed in the peripheral direction on a radially outer edge. In one illustrative embodiment, tab 306A and tab 306B are each directed radially outward and are disposed in a radial location that is substantially toward first end section 303A and 303B respectively. In this embodiment, each section of front TB 300A and rear TB 300B include a first thickness and a second thickness wherein the first thickness is greater than the second thickness. Much like front TB 100A and rear TB 100B, front TB 300A and rear TB 300B each include a plurality of notched/beveled sections wherein each bearing arc has reduced thickness (i.e. the second thickness) in the notched/beveled area.

[00031] Front TB 300A includes notch/bevel 310A, notch/bevel 312A, notch/bevel 314A and notch/bevel 316A while rear TB 300B includes notch/bevel 310B, notch/bevel 312B, notch/bevel 314B and notch/bevel 316B. Notch 310A and notch 310B are located respectively on front top TB 302A and rear top TB 302B directly adjacent tab 306A and 306B at a radial location that is substantially toward first end section 303A and 303B. Notch 312A is located on front bottom TB 304A and comprises two sections wherein both sections are located directly adjacent tab 308A and at a radial location toward third end section 305A. In contrast, notch 312B is located on rear bottom TB 304B and comprises two sections wherein both sections are located directly adjacent tab 308B and at a radial location toward fourth end section 309B. Notch 314A and notch 316A are located directly adjacent second end section 307A and fourth end section 309A respectively.

[00032] In one embodiment, front TB 300A may be installed within a channel in the engine block that is located intermediate the engine block and the crank shaft. In this embodiment, front TB 300A may be rotated to facilitate installation. Notch 314A and 316A are designed to substantially mitigate the possibility of the end sections of front TB 300A being obstructed or damaged while TB 300A is being rotated into a locking or coupling position during installation within the channel intermediate the engine block and crankshaft. The description of the notched/beveled sections of 314B and 316B of rear TB 300B is substantially the same as the

description of notched sections 314A and 316A of front TB 300A. Notch/bevel 310A and 312A along with notch/bevel 310B and 312B each function as relief sections configured to avoid stress or wear in the area of the thrust bearings adjacent corresponding tab locations 306A, 308A, 306B and 308B. The notch/bevel sections reduce or prevent contact between front TB 300A and the MBC and between rear TB 300B and the MBC, in the area adjacent the corresponding tab locations, when the thrust bearings are installed within/coupled to the MBC. Notch/bevel 310A, 312A, and notch/bevel 310B, 312B therefore each cooperate to minimize and/or mitigate damage to the thrust bearings during mechanical coupling to the MBC.

[00033] In one embodiment, notch/bevel 310A, 312A, and notch/bevel 310B, 312B each provide a cut-back area having reduced thickness (i.e. the second thickness) relative to the thickness of the remaining non-beveled areas (i.e. the first thickness) of TB 300A and TB 300B. Certain corner sections of an engine block may include sharp edges which are present as a result of engine block machining operations. The cut-back allows for a small fillet into the corresponding adjacent tabs, 306A/B and 308A/B, that prevents the fillet from impacting a particular sharp edge/corner area of an engine block. Additionally, the cut-back includes a slight thickness reduction which allows a cross section of the cut-back area to be similar to a cross section of non-beveled areas of front TB 300A and rear TB 300B. The slight thickness reduction allows the cut-back areas to be capable of withstanding thrust loads that are substantially similar to thrust loads experienced by other non-beveled areas of TB 300A and TB 300B.

[00034] FIGs. 4A and 4B illustratively show the individual sections of the thrust bearings of FIGs. 3A and 3B that couple/interface to form a pair of uni-directional thrust bearings, front TB assembly 400A and rear TB assembly 400B, in accordance with the present disclosure. Front TB 400A includes two distinct bearing arc sections, namely top TB 302A and bottom TB 304A, that couple/interface to form front TB 400A. Likewise, rear TB 400B includes two distinct bearing arc sections, namely top TB 302B and bottom TB 304B, that couple/interface to form rear TB 400B. As shown in the illustrative embodiment of FIGs. 4A and 4B, front top TB 302A and front bottom TB 304A may interface or contact one another at interface location 402A and 404A to form front TB assembly 400A. Likewise, rear top TB 302B and rear bottom TB 304B may interface or contact one another at interface location 402B and 404B to form rear TB assembly 400B.

[00035] As described above and as further shown in the illustrative embodiment of FIGs. 4A and 4B, front TB 400A and rear TB 400B provide an asymmetric full round axial thrust bearing that allows for correct installation within a MBC of an engine. The asymmetric full round axial bearings of FIGs. 4A and 4B are defined by four distinct bearing sections each having a unique sweep angle and tab position location that provides substantial mitigation against incorrect thrust bearing installation. Front TB 400A includes an arc profile having tab positions and notched/beveled sections which may be unique to the front section of the MBC of an internal combustion engine. Likewise, rear TB 400B includes an arc profile having tab positions and notched/bevel sections which may be unique to the rear section of the MBC of an internal combustion engine. Hence, front TB 400A is designed to substantially prevent incorrect installation when the thrust bearing is installed into the front/forward section of a MBC. Similarly, rear TB 400B is designed to substantially prevent incorrect installation when the thrust bearing is installed in the rear/rearward section of a MBC.

[00036] In the illustrative embodiment of FIGs. 4A and 4B, the arc profile of front top TB 302A and rear top TB 302B may each include a sweep angle that exceeds 180° relative to the X-axis, while the arc profile of front bottom TB 304A and rear bottom 304B may each include a sweep angle that is less than 180° relative to the X-axis. In one illustrative embodiment, top TB 302A includes a sweep angle corresponding approximately to 190° relative to the X-axis, while top TB 302B includes a sweep angle corresponding approximately to 200° relative to the X-axis. Although top TB 302A and top TB 302B may each have sweep angles that are greater than 180° (relative to the X-axis), the distinctive sweep angles for each arc profile allows for intentional interference if, for example, rear bottom TB 304B was to be installed in the position of an engine block or MBC configured to receive front bottom TB 304A. In one embodiment, front top TB 302A and rear top TB 302B may each have tabs, 306A and 306B respectively, positioned radially generally at 90°, however TB 302A includes an additional arc section 301A having a reduced thickness wherein arc section 301A is disposed adjacent end section 303A. Hence, section 301A, in combination with the 190° sweep angle (relative to the X-axis), gives TB 302A a unique design such that only TB 302A may be installed in the section of the engine block or MBC configured for front top TB 302A.

[00037] Additionally, as described above, regarding front bottom TB 304A and rear bottom TB 304B, each arc profile includes tabs (308A/B respectively) disposed in distinct

peripheral locations on the radially outer edge of each bearing section. In one embodiment, TB 304A includes tab 308A disposed on its radially outer edge at a location corresponding approximately to 135° relative to the Y-axis (or approximately 45° relative to the X-axis), while TB 304B includes tab 308B disposed on its radially outer edge at a location corresponding approximately to 180° relative to the Y-axis (or approximately 90° relative to the X-axis). Tabs 308A and 308B may be received within cast pockets disposed at locations within the MBC that correspond to the locations of tabs 308A and 308B along the arc profile of TB 304A and TB 304B respectively. Accordingly, front bottom TB 304A cannot be installed in the location of the engine configured to receive rear bottom TB 304B, likewise rear bottom TB 304B cannot be installed in the location of the engine configured to receive front bottom TB 304A. Hence, the present disclosure provides a unique crankshaft thrust bearing geometry wherein, for example, front TB assembly 400A and rear TB assembly 400B cannot be installed in an incorrect location within an engine. Therefore, the thrust bearing sets provide a fail-safe design for MBC installation.

[00038] FIG. 5A shows the uni-directional thrust bearing (front TB 400A) of FIG. 4A installed in the front section of an internal combustion engine in accordance with the present disclosure. Assembly 500A includes engine cylinder block 502A, main bearing cap ("MBC") 504A, front mating surface 506A, front crankshaft section 508A, and bearing section 510A. As is known in the art, during assembly of an internal combustion engine, the engine block is coupled with the MBC. Thus, mating surface 506A defines an interface location wherein cylinder block 502A mates with MBC 504A. In the illustrative embodiment of FIG. 5A, MBC 504A includes an upper cast pocket 512A configured to receive tab 306A of front top TB 302A. Additionally, MBC 504A may further include a lower cast or machined pocket 514A configured to receive tab 308A of front bottom TB 304A. Assembly 500A further includes bearing section 510A extending longitudinally from the mating 506A to end section 307A and including a section length greater than 10mm. In one illustrative embodiment, bearing section 510A includes a section length of approximately 17.8mm.

[00039] FIG. 5A further shows front TB 400A of FIG. 4A in a fully assembled arrangement within the engine block and MBC of an internal combustion engine. In one embodiment of the present disclosure, MBC 504A may be in an inverted orientation to facilitate mating engine cylinder block 502A to MBC 504A. Also, each section of front TB assembly

400A is capable of mechanical coupling to MBC 504A. As noted above, front bottom TB 304A includes tab 308A having a unique tab design. Tab 308A permits bottom TB 304A to be securely coupled to MBC 504A despite gravity exerting a downward push force when MBC 504A is inverted. Thus, tab 308A allows for ease of installation wherein bottom TB 304A may remain coupled to MBC 504A when MBC 504A is in an inverted orientation. The illustrative embodiment of FIG. 5A provides an asymmetric full round axial thrust bearing (e.g. front TB 400A) that allows for correct installation due to unique tab location and unique sweep angle arc profile. Moreover, assembly 500A is substantially fail safe due to the asymmetrical sweep used to distribute thrust loads applied to the thrust bearing during clockwise (forward view) crankshaft rotation during operation of an internal combustion engine. In one illustrative embodiment, main bearing section 516 includes an upper bearing section 518 and a lower bearing section 520 wherein upper bearing section 518 includes a front section 519A and lower bearing section 520 also includes a front section 521A.

[00040] FIG. 5B shows the uni-directional thrust bearing (rear TB 400B) of FIG. 4B installed in the rear section of an internal combustion engine in accordance with the present disclosure. Assembly 500B includes substantially the same components as assembly 500A and simply provides a rearward view of the above mentioned components wherein designators corresponding to the rearward view include a suffix "B". As such, assembly 500B includes engine cylinder block 502B, MBC 504B, mating surface 506B, crankshaft section 508B and bearing section 510B. Mating surface 506B defines an interface location wherein cylinder block 502B mates with MBC 504B. In the illustrative embodiment of FIG. 5B, MBC 504B includes an upper cast or machined pocket 512B configured to receive tab 306B of rear top TB 302B. Additionally, MBC 504B may further include a lower cast or machined pocket 514B configured to receive tab 308B of rear bottom TB 304B. Assembly 500B further includes bearing section 510B extending longitudinally from the mating 506B to end section 307B and including a section length greater than 10mm. In one illustrative embodiment, bearing section 510B includes a section length of approximately 35.2mm.

[00041] FIG. 5B further shows rear TB 400B of FIG. 4B in a fully assembled arrangement within the engine block and MBC of an internal combustion engine. In one embodiment of the present disclosure, MBC 504B may be in an inverted orientation to facilitate mating engine cylinder block 502B to MBC 504B. Also, each section of rear TB assembly 400B is capable of

mechanical coupling to MBC 504B. As described above, rear bottom TB 304B includes tab 308B having a unique tab design. Tab 308B permits rear bottom TB 304B to be securely coupled to MBC 504B despite gravity exerting a downward push force when MBC 504B is inverted. Thus, tab 308B allows for ease of installation wherein bottom TB 304B may remain coupled to MBC 504B when MBC 504B is in an inverted orientation. The illustrative embodiment of FIG. 5B provides an asymmetric full round axial thrust bearing (e.g. rear TB 400B) that allows for correct installation due to unique tab location and unique sweep angle arc profile. Moreover, assembly 500B is substantially fail safe due to the asymmetrical sweep used to distribute thrust loads applied to the thrust bearing during counter-clockwise (rearward view) crankshaft rotation during operation of an internal combustion engine. In one illustrative embodiment, upper bearing section 518 also includes a rear section 519B and lower bearing section 520 also includes a rear section 521B.

[00042] In the foregoing specification, specific embodiments of the present disclosure have been described. However, one of ordinary skill in the art will appreciate that various modifications and changes can be made without departing from the scope of the disclosure as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of disclosure. The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of any or all the claims. The disclosure is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued. Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the spirit and scope of the invention as described and defined in the following claims.

CLAIMS

We claim:

1. A bearing assembly comprising:

a first bearing comprising a first section having a first arcuate length and a second section having a second arcuate length wherein the first arcuate length is greater than the second arcuate length;

a second bearing comprising a third section having a third arcuate length and a fourth section having a fourth arcuate length wherein the third arcuate length is greater than the fourth arcuate length;

a first tab disposed on the first section of the first bearing and a second tab disposed on the second section of the first bearing; and

a third tab disposed on the third section of the second bearing and a fourth tab disposed on the fourth section of the second bearing.

2. The bearing assembly of claim 1, further comprising a main bearing cap comprising an upper forward end, a lower forward end, an upper rearward end and a lower rearward end, the main bearing cap configured to:

receive, in the upper forward end, the first section of the first bearing;

receive, in the lower forward end, the second section of the first bearing;

receive, in the upper rearward end, the third section of the second bearing;

receive, in the lower rearward end, the fourth section of the second bearing.

3. The bearing assembly of claim 2, wherein the first tab is disposed on the first section at a first circumferential position and the second tab is disposed on the second section at a second circumferential position that is different from the first circumferential position.

4. The bearing assembly of claim 2, wherein the third tab is disposed on the third section at a first circumferential position and the fourth tab is disposed on the fourth section at a second circumferential position that is different from the first circumferential position.

5. The bearing assembly of claim 2, wherein the first section opposes the second section when the first bearing is received by a forward end of the main bearing cap and, wherein the third section opposes the fourth section when the second bearing is received by a rearward end of the main bearing cap.

6. The bearing assembly of claim 1, wherein the first and second sections each comprise a first end, a second end, a first beveled area disposed toward the first end, and a second beveled area disposed directly adjacent the second end.

7. The bearing assembly of claim 6, wherein the third and fourth sections each comprise a first end and a second end, and wherein the third section comprises a first beveled area disposed adjacent the first end and a second beveled area disposed directly adjacent the second end, and the fourth section comprises a first beveled area disposed directly adjacent the fourth tab and a second beveled area disposed directly adjacent the second end.

8. The bearing assembly of claim 7, wherein the beveled areas of the first and second bearings are structured to mitigate damage to the bearings when the first and second bearings are received by a main bearing cap of an engine.

9. An apparatus, comprising:

a first bearing comprising an upper section and a lower section and at least one tab disposed along an outer radial portion of the first bearing, the upper section having arcuate length that is greater than an arcuate length of the lower section; and

a second bearing comprising an upper section and a lower section and at least one tab disposed along an outer radial portion of the second bearing, the upper section having arcuate length that is greater than an arcuate length of the lower section;

wherein a circumferential location of the at least one tab of the first bearing and the arcuate length of the upper and lower sections of the first bearing are configured to correspond to a forward end of a main bearing cap; and

wherein a circumferential location of the at least one tab of the second bearing and the arcuate length of the upper and lower sections of the second bearing are configured to correspond to a rearward end of the main bearing cap.

10. The apparatus of claim 9, wherein an asymmetry in the arcuate length of the upper and lower sections of the first bearing and an asymmetry in the arcuate length of the upper and lower sections of the second bearing distribute thrust loads applied to the first and second bearings during operation of an engine.

11. The apparatus of claim 9, wherein the upper section of the first bearing comprises a first end and a second end, a first tab disposed adjacent the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end.

12. The apparatus of claim 11, wherein the lower section of the first bearing comprises a first end and a second end, a second tab disposed toward the first end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end.

13. The apparatus of claim 9, wherein the upper section of the second bearing comprises a first end and a second end, a first tab disposed at the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end.

14. The apparatus of claim 13, wherein the lower section of the second bearing comprises a first end and a second end, a second tab disposed toward the second end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end.

15. The apparatus of claim 12, wherein the first tab of the first bearing is received within a first cast pocket of the main bearing cap and the second tab of the first bearing is received within a second cast pocket of the main bearing cap.

16. The apparatus of claim 14, wherein the first tab of the second bearing is received within a third cast pocket of the main bearing cap and the second tab of the second bearing is received within a fourth cast pocket of the main bearing cap.

17. An apparatus, comprising:

an engine comprising a main bearing cap having a forward end and a rearward end;

a first bearing disposed at the forward end, the first bearing comprising at least one tab, an upper section, a lower section, and an asymmetry in an arcuate length of the upper and lower sections; and

a second bearing disposed at the rearward end, the second bearing comprising at least one tab, an upper section, a lower section, and an asymmetry in an arcuate length of the upper and lower sections;

wherein a circumferential location of the at least one tab of the first bearing and the asymmetry in the arcuate length of the first bearing are configured to correspond to a forward end of the main bearing cap; and

wherein a circumferential location of the at least one tab of the second bearing and the asymmetry in the arcuate length of the second bearing are configured to correspond to a forward end of the main bearing cap.

18. The apparatus of claim 17, wherein the asymmetry in the arcuate length of the upper and lower sections of the first bearing and the asymmetry in the arcuate length of the upper and lower sections of the second bearing distribute thrust loads applied to the first and second bearings during operation of the engine.

19. The apparatus of claim 17, wherein the upper section of the first bearing comprises a first end and a second end, a first tab disposed adjacent the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end.

20. The apparatus of claim 19, wherein the lower section of the first bearing comprises a first end and a second end, a second tab disposed toward the first end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end.

21. The apparatus of claim 17, wherein the upper section of the second bearing comprises a first end and a second end, a first tab disposed at the first end, a first beveled area disposed adjacent the first tab, and a second beveled area disposed adjacent the second end.

22. The apparatus of claim 21, wherein the lower section of the second bearing comprises a first end and a second end, a second tab disposed toward the second end, a first beveled area disposed adjacent the second tab, and a second beveled area disposed adjacent the second end.

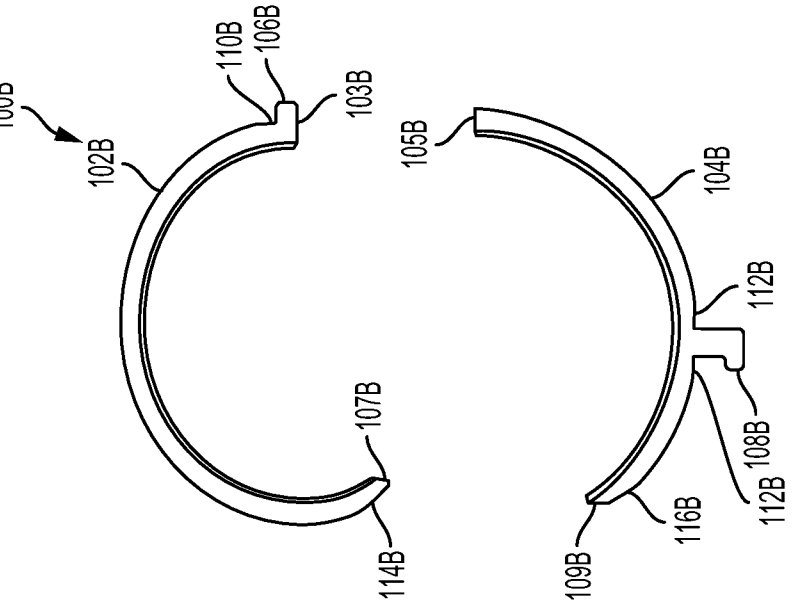
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FIG. 1B

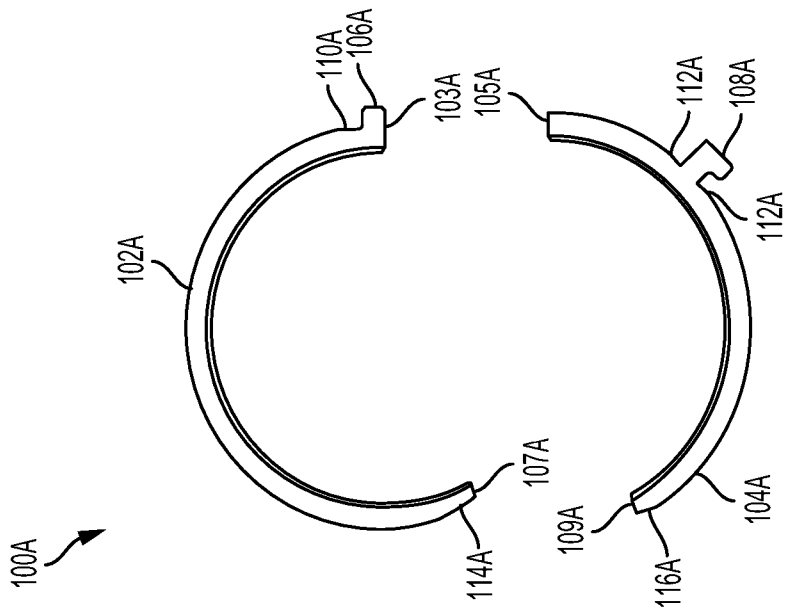
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FIG. 1A

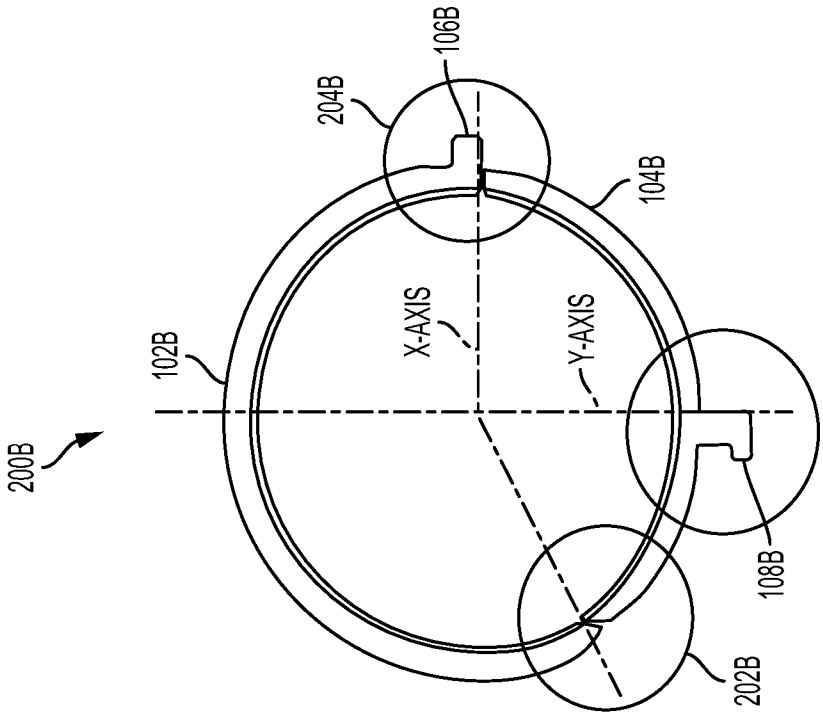
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FIG. 2B

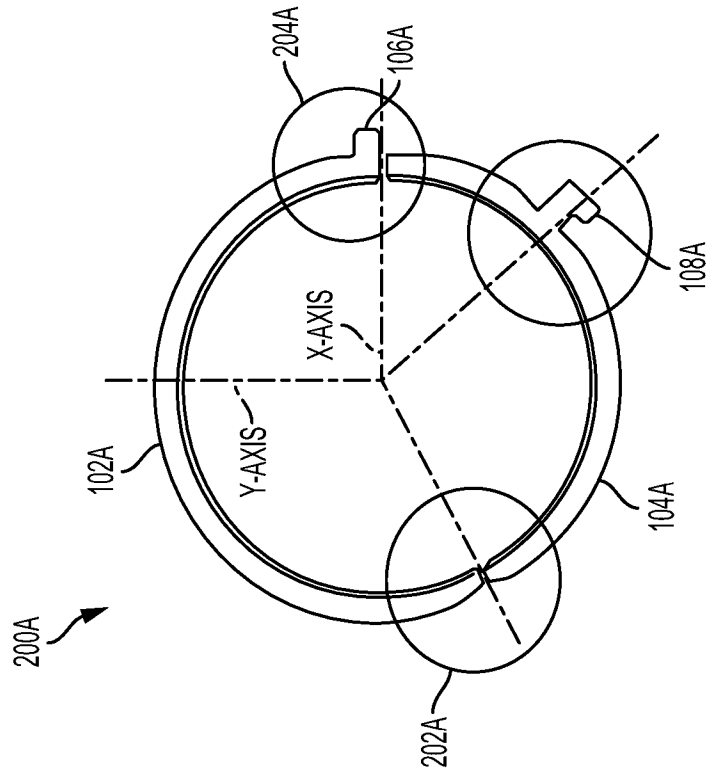
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FIG. 2A

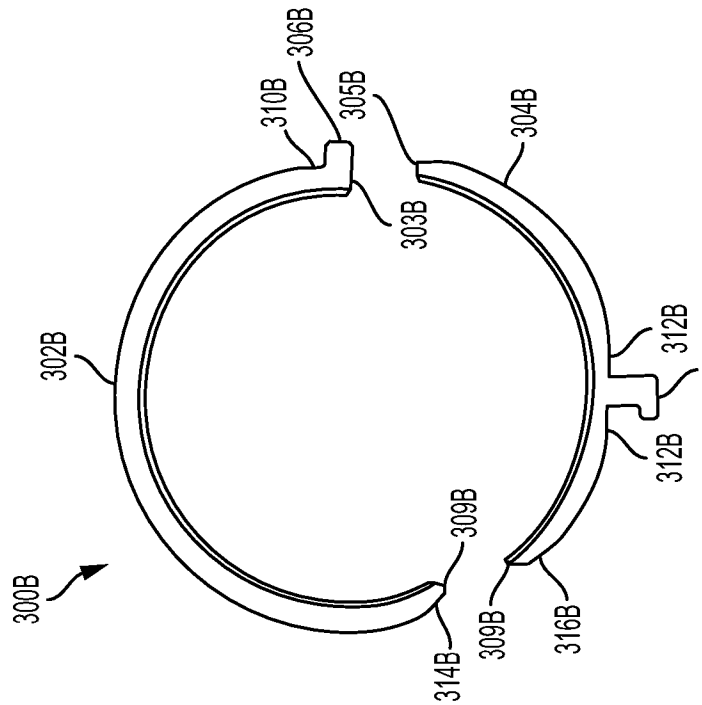
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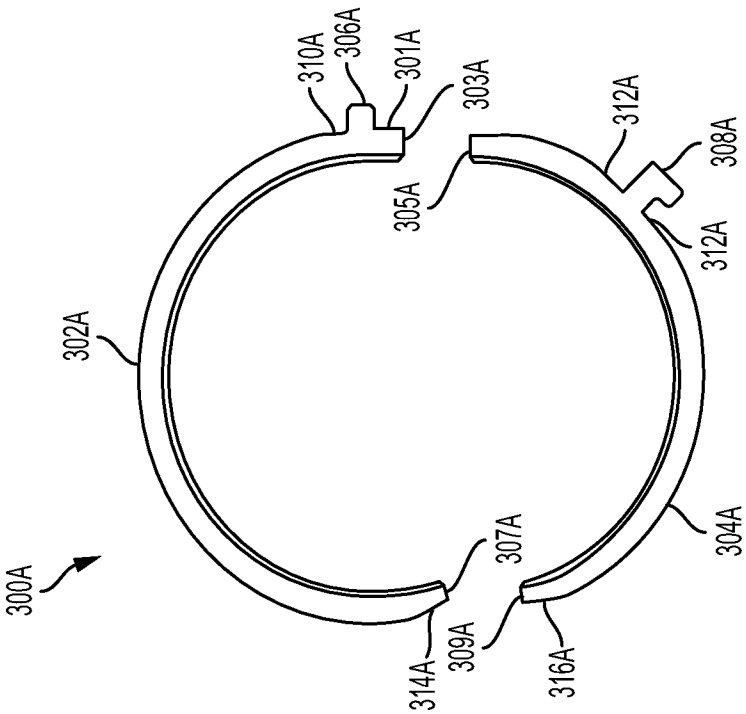
FIG. 3B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301A

FIG. 3A

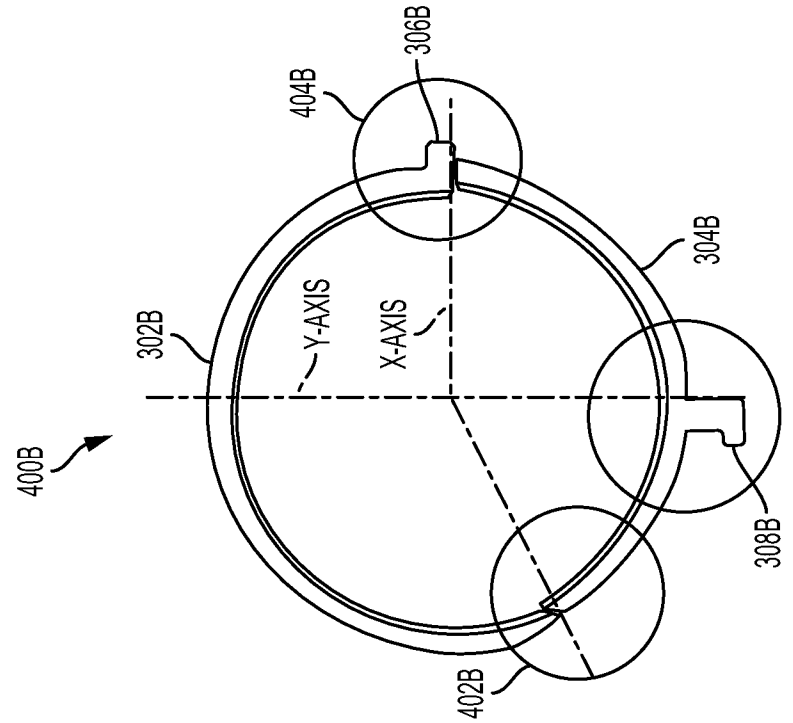
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FIG. 4B

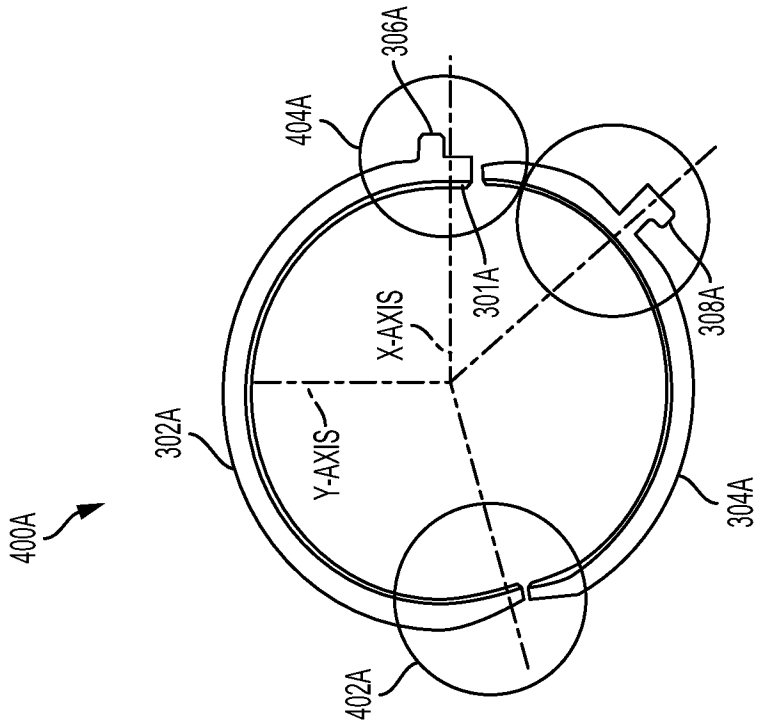
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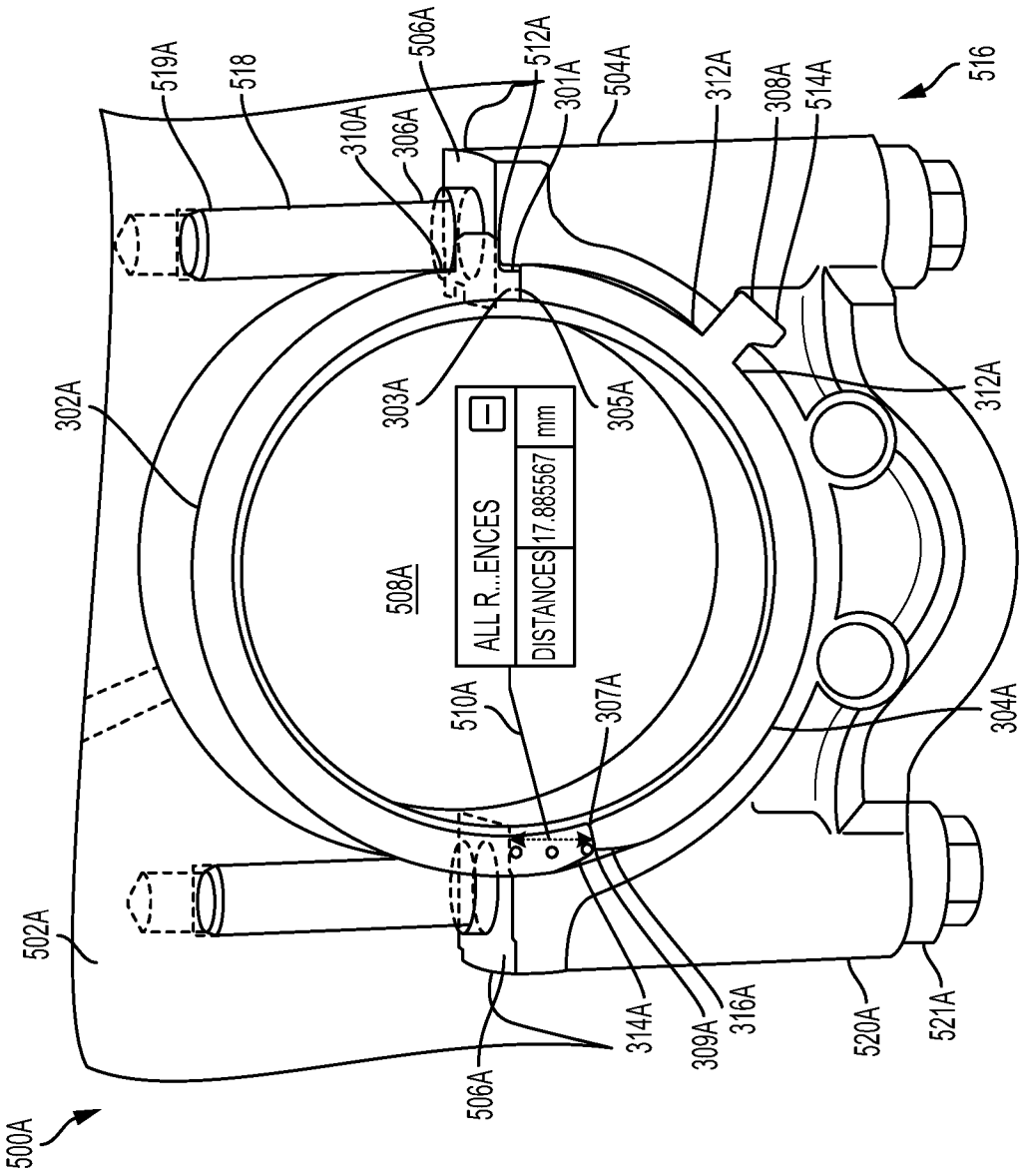
FIG. 4A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316A
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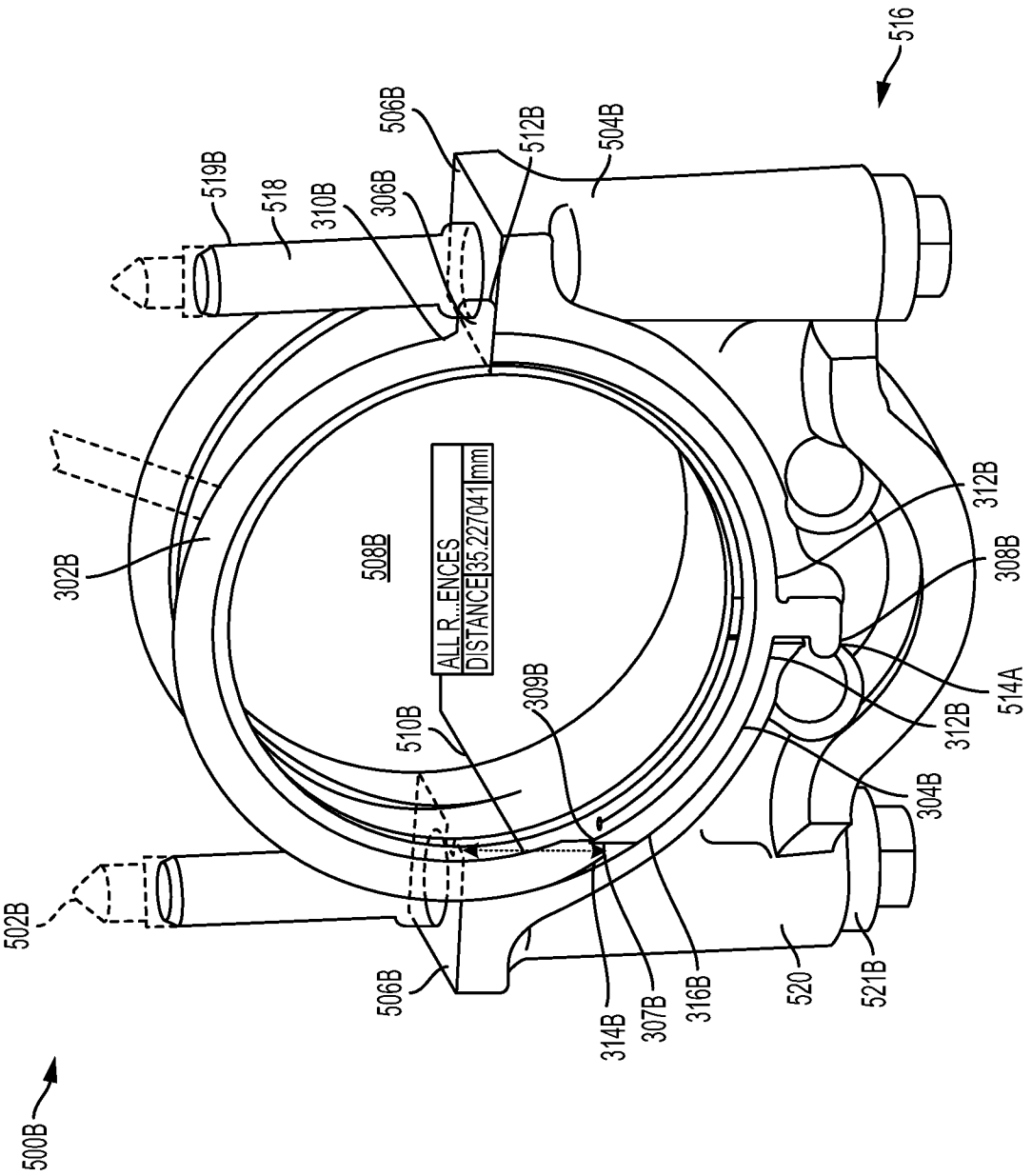
521A
506A

FIG. 5A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508B
ALL R...ENCES
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312B
308B
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502B
506B
314B
307B
316B
520
521B
500B

FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/26216

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F16C 9/02, 9/04 (2016.01)
CPC - F16C 9/02, 9/04
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)
IPC(8) Classifications: F16C 9/02, 9/04 (2016.01)
CPC Classifications: F16C 9/02, 9/04

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)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); EBSCO, Google, Google Scholar
Bearing, washer, thrust, crankshaft, arcuate, length, longer, shorter, asymmetric, engine, bevel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0135713 A1 (WELCH SM) 23 June 2005; figures 6, 9; paragraph [0032]	1, 6, 7, 8
Y	US 2007/0081748 A1 (SITTER DH) 12 APril 2007; figures 2, 8	1-5
Y	US 2013/0004103 A1 (SHAFFER BJ) 03 January 2013; figures 4, 5; paragraph [0008]	1-5
Y	US 4,674,455 A (TSUBOI HGK) 23 June 1987; figures 2, 3; column 1, lines 20-35	2-5
A	US 2012/0243815 A1 (KUWABARA A) 27 September 2012; entlre document	1-8
A	US 2014/0233874 A1 (DAIDO METAL COMPANY) 21 August 2014; entire document	1-8

☐ 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
15 June 2016 (15.06.2016)	22 AUG 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/26216

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-***-Continued Within the Next Supplemental Box-***-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Group I: Claims 1-8

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US16/26216

-***-Continued from Box No. III Observations where unity of invention is lacking-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-8 are directed toward a bearing assembly comprising a first tab disposed on a first section of a first bearing and a second tab disposed on a second section of a first bearing; and a third tab disposed on a third section of a second bearing and a fourth tab disposed on a fourth section of a second bearing.

Group II: Claims 9-22 are directed toward an engine comprising a main bearing cap having a forward end and a rearward end; a first bearing disposed at the forward end, and a second bearing disposed at the rearward end, wherein a circumferential location of the at least one tab of the first bearing and the asymmetry in the arcuate length of the first bearing are configured to correspond to a forward end of the main bearing cap; and wherein a circumferential location of the at least one tab of the second bearing and the asymmetry in the arcuate length of the second bearing are configured to correspond to a forward end of the main bearing cap.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

The special technical features of Group I include a third tab disposed on the third section of the second bearing and a fourth tab disposed on the fourth section of the second bearing (which is not present in Group II).

The special technical features of Group II include an engine comprising a main bearing cap having a forward end and a rearward end; a first bearing disposed at the forward end, and a second bearing disposed at the rearward end, wherein a circumferential location of the at least one tab of the first bearing and the asymmetry in the arcuate length of the first bearing are configured to correspond to a forward end of the main bearing cap; and wherein a circumferential location of the at least one tab of the second bearing and the asymmetry in the arcuate length of the second bearing are configured to correspond to a forward end of the main bearing cap (which is not present in Group I).

The common technical features of Groups I and II include a first bearing comprising a first section having a first arcuate length and a second section having a second arcuate length wherein the first arcuate length is greater than the second arcuate length; a second bearing comprising a third section having a third arcuate length and a fourth section having a fourth arcuate length wherein the third arcuate length is greater than the fourth arcuate length; a first tab disposed on the first section of the first bearing and a second tab disposed on the second section of the first bearing.

These common technical features are disclosed by US 2005/0135716 A1 to WELCH, S et al. (hereinafter 'Welch'). Welch discloses a first bearing (bearing body 14' and washer 38', collectively; figure 9; paragraph [0032]) comprising a first section (38'; figure 9) having a first arcuate length (as shown; figure 9) and a second section (14'; figure 9) having a second arcuate length (as shown; figure 9) wherein the first arcuate length (of 38') is greater than the second arcuate length (of 14', as shown; figures 2, 3, 9; paragraph [0032]); a second bearing (bearing body 12' and washer 36'; figure 9) comprising a third section (36') having a third arcuate length (as shown; figure 9) and a fourth section (12'; figure 9) having a fourth arcuate length (as shown; figure 9) wherein the third arcuate length (of 36') is greater than the fourth arcuate length (of 12', as shown; figures 2, 3, 9; paragraph [0032]); a first tab (tab 56'; figure 9) disposed on the first section (38') of the first bearing (as shown; figure 9) and a second tab (tab is shown on face 26'; figure 9) disposed on the second section (14') of the first bearing (as shown; figure 9).

Because the common technical features are disclosed by Welch, the inventions are not so linked as to form a single general inventive concept. Therefore, Groups I and II lack unity.