US010385918B1

(12) United States Patent
Germano

(10) Patent No.: US 10,385,918 B1
(45) Date of Patent: Aug. 20, 2019

(54) BEARING WITH VISCO-METAL LAYERS REACTIVE TO INCREASE DYNAMICALLY CLEARANCE AND MINIMUM OIL FILM THICKNESS

(71) Applicant: **GM Global Technology Operations LLC**, Detroit, MI (US)

(72) Inventor: **Francesco Germano**, Turin (IT)

(73) Assignee: **GM GLOBAL TECHNOLOGY OPERATIONS, LLC**, Detroit, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/042,270**

(22) Filed: **Jul. 23, 2018**

(51) **Int. Cl.**
F16C 17/02 (2006.01)
F16C 33/10 (2006.01)
F16C 33/12 (2006.01)
F16C 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***F16C 33/106*** (2013.01); ***F16C 9/04*** (2013.01); ***F16C 17/02*** (2013.01); ***F16C 33/125*** (2013.01)

(58) **Field of Classification Search**
CPC F16C 33/106; F16C 9/04; F16C 17/02; F16C 33/125; F16C 27/063
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,707,149 A * 11/1987 Hahle B60G 21/0551 384/276
5,707,155 A * 1/1998 Banfield F16C 33/06 384/276
6,964,521 B2 * 11/2005 McDearmon B64C 13/24 384/10
6,981,798 B2 * 1/2006 Katagiri F16C 9/04 384/294
9,080,604 B2 * 7/2015 Rossmanith F16C 17/022
9,863,472 B2 1/2018 Tamai et al.
10,082,177 B2 * 9/2018 Fisher F16C 9/02

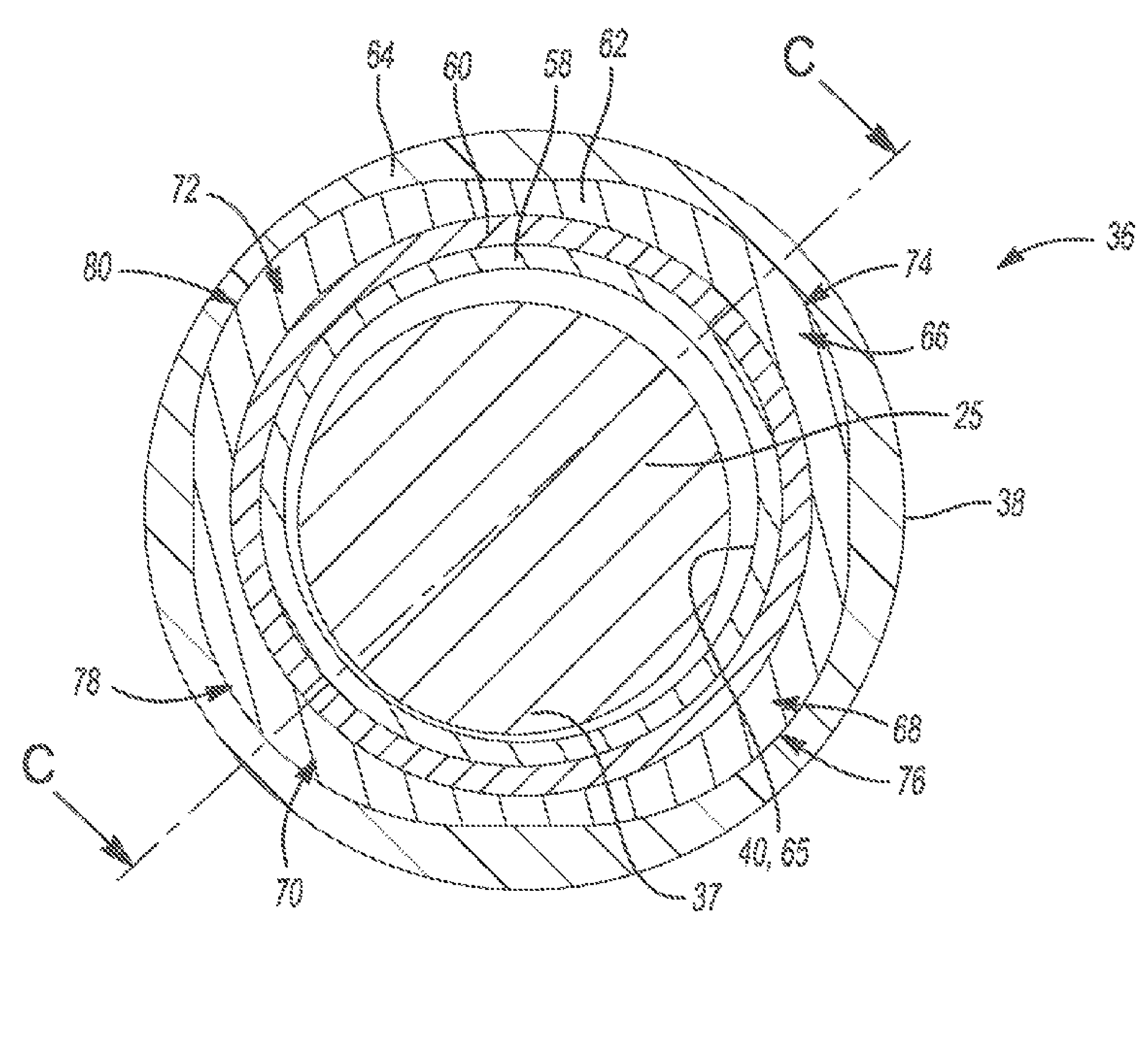
* cited by examiner

Primary Examiner — Thomas R Hannon

(57) **ABSTRACT**

A bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine includes a plurality of bearing portions joined together and forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component. The bearing having a plurality of bearing layers made of different materials unevenly distributed about a circumference and along a longitudinal axis of the bearing, the bearing layers reactively ovalizing in response to loads imparted by the non-homogeneously or homogeneously rotating components, and changing a minimum lubricating fluid thickness on a portion of the substantially cylindrical central bore that ovalizes in response to transient local loads imparted by the non-homogeneously or homogeneously loaded rotating component.

20 Claims, 4 Drawing Sheets



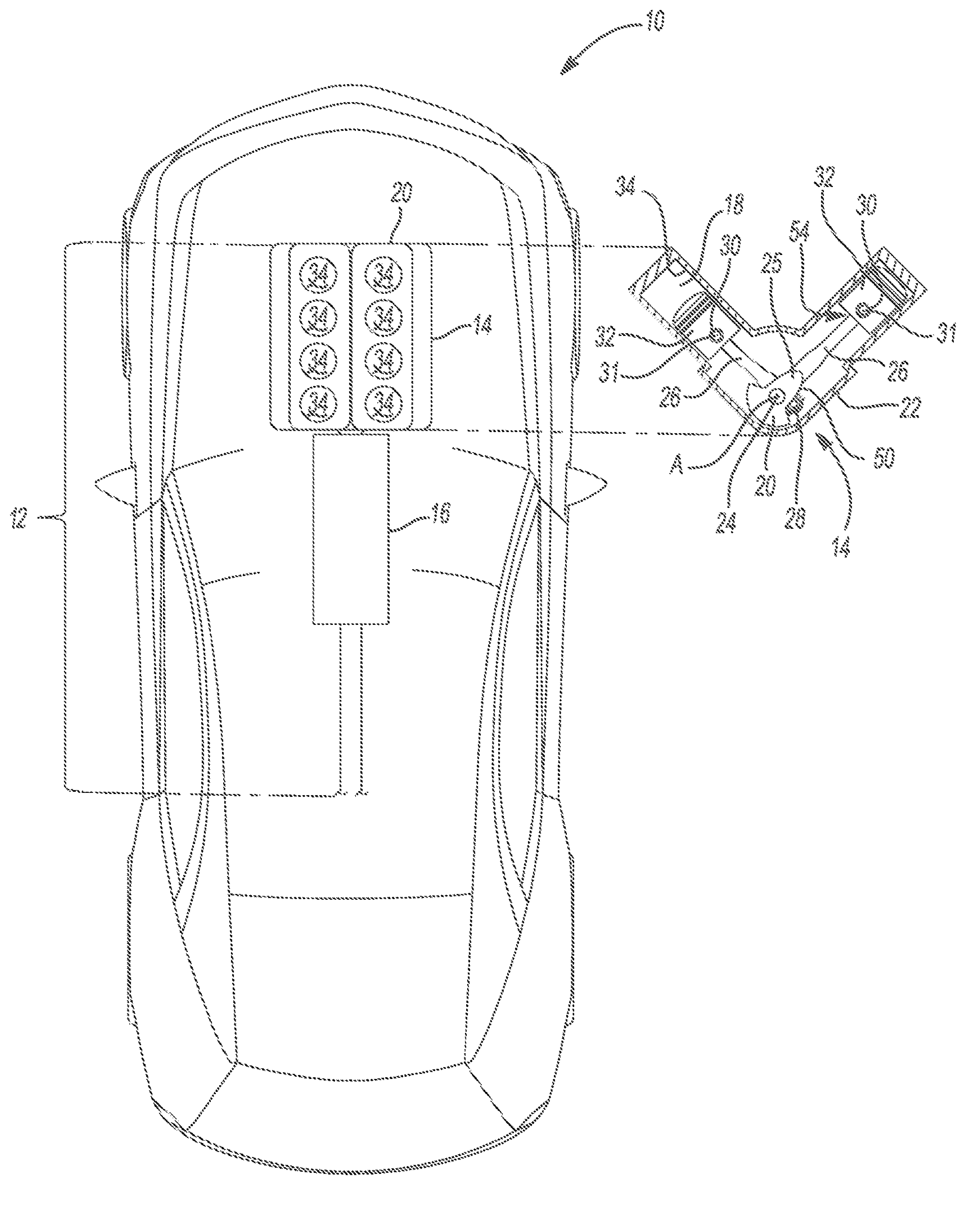


FIG. 1

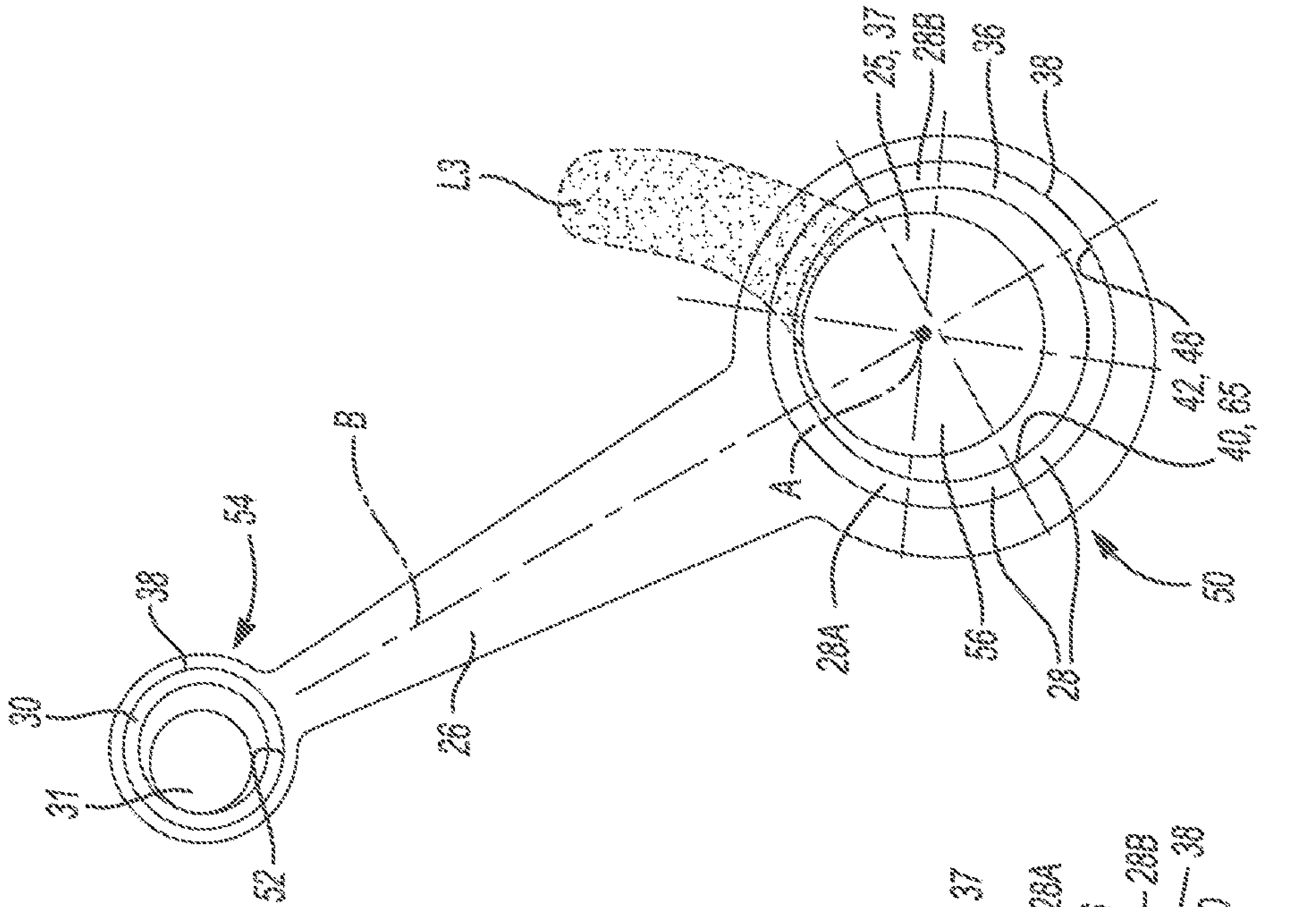


FIG. 2C

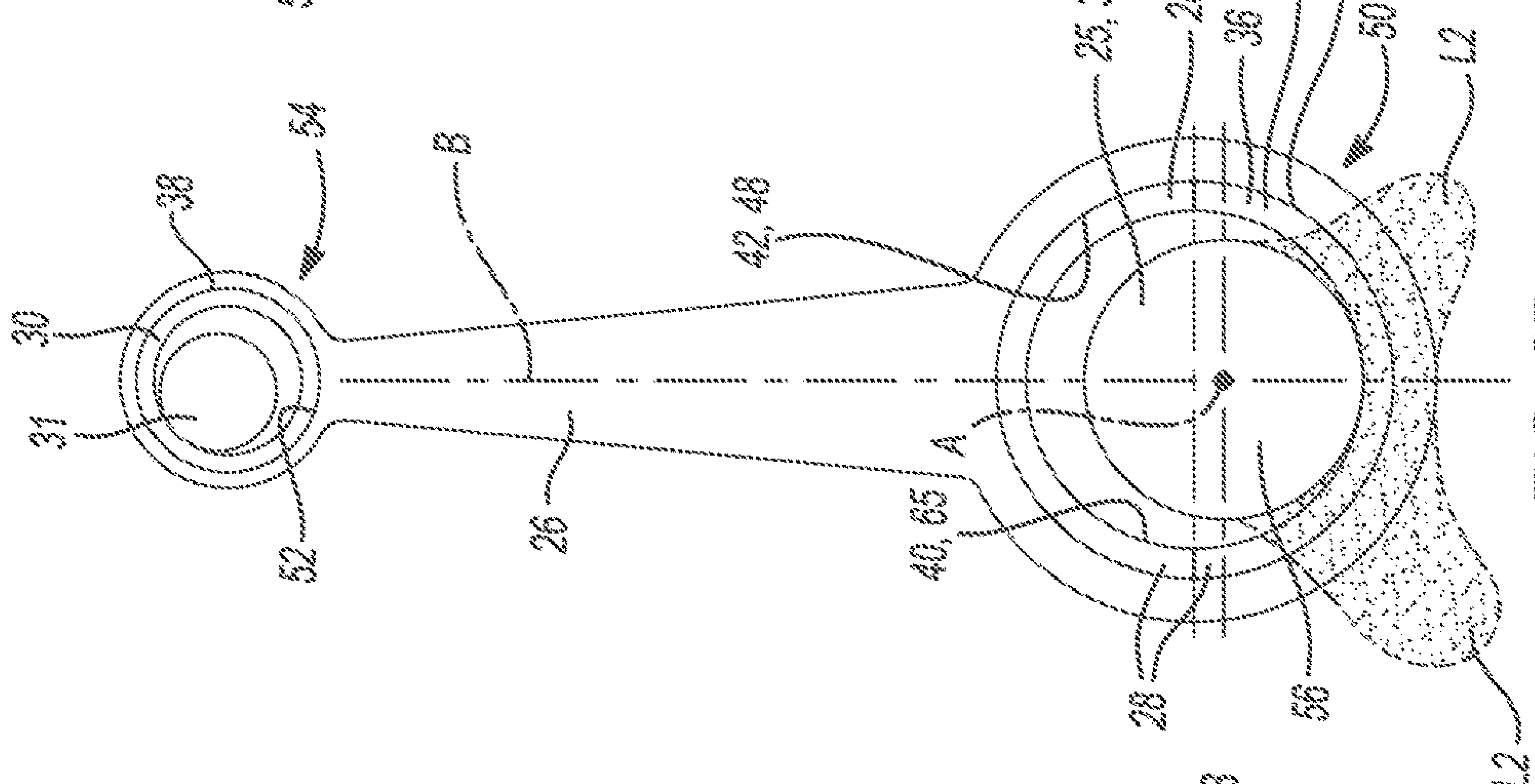


FIG. 2B

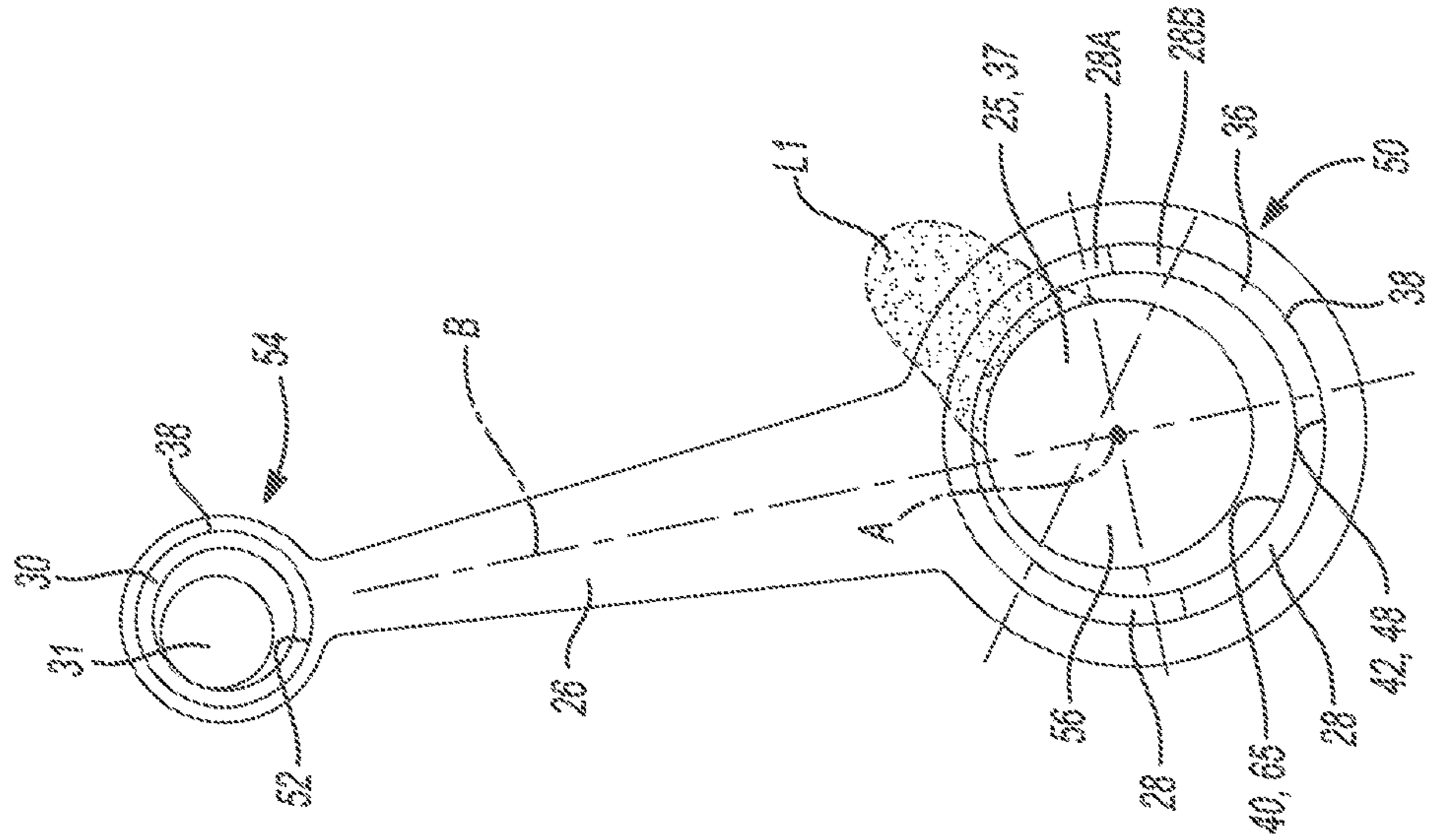
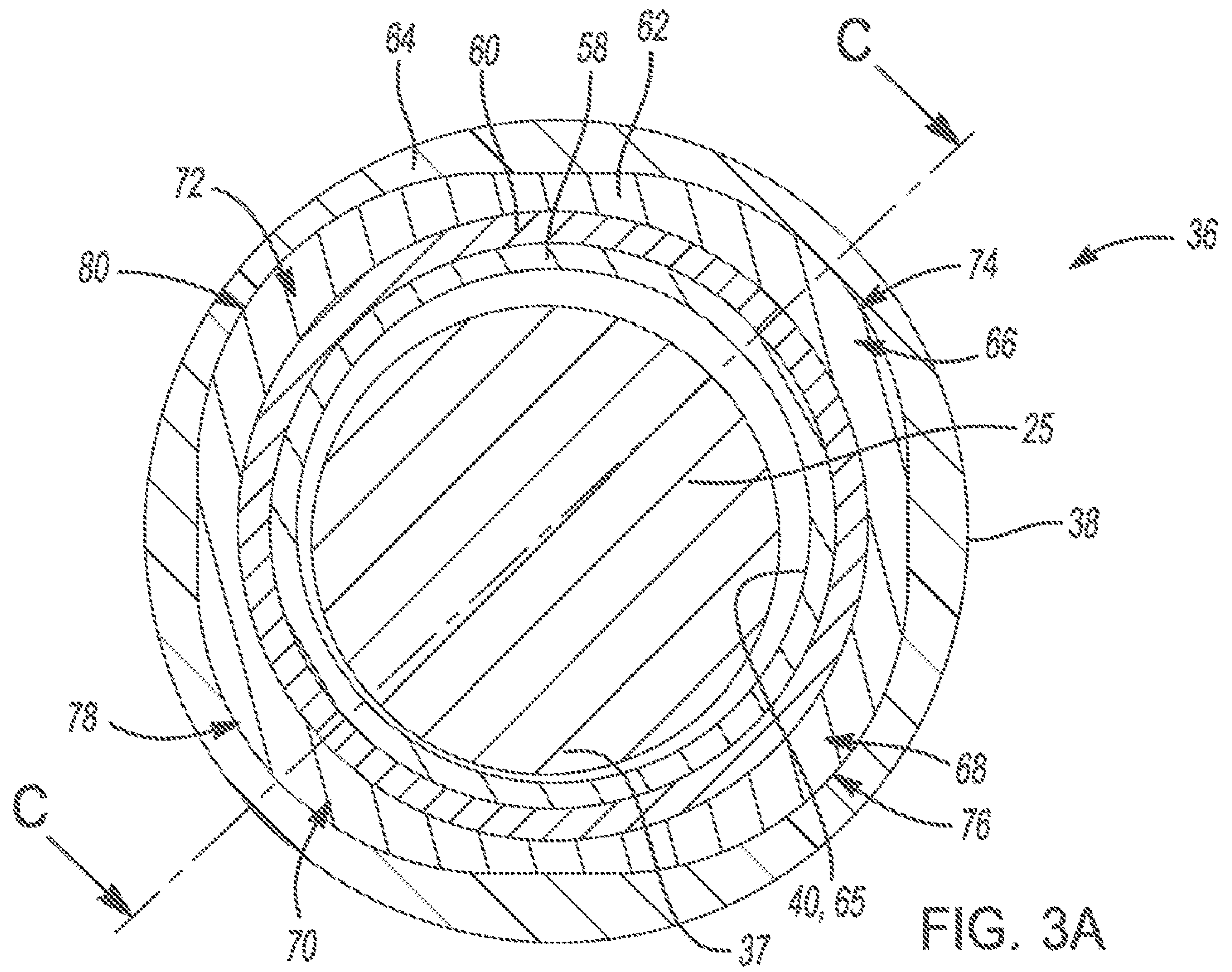
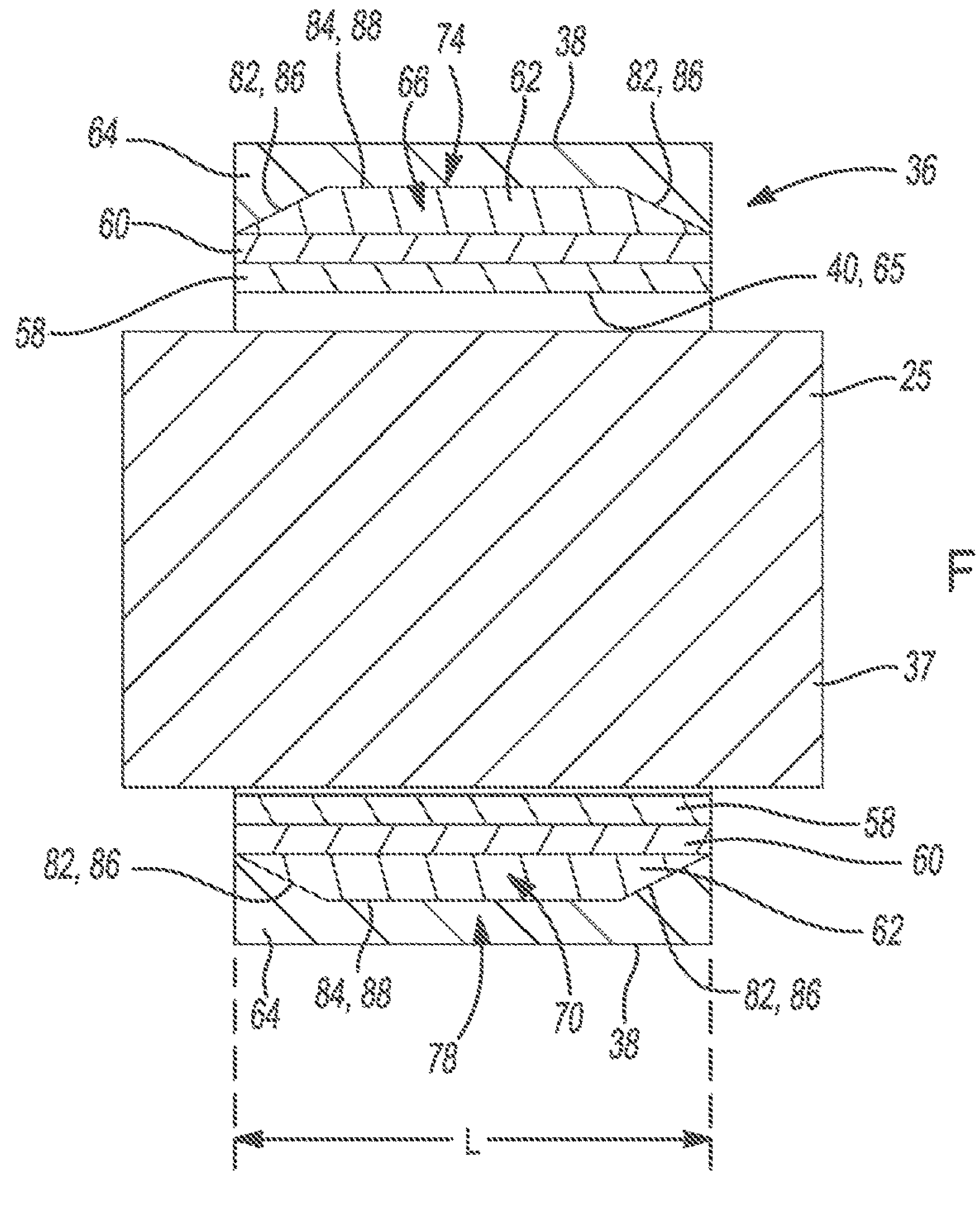


FIG. 2A



64
60
58
62
C
72
36
80
74
66
25
38
78
68
C
76
40, 65
70
37

FIG. 3A



84, 88
74
38
82, 86
66
62
82, 86
64
36
60
40, 65
58
25
37
58
82, 86
60
62
64
84, 88
70
38
82, 86
78
L

FIG. 3B

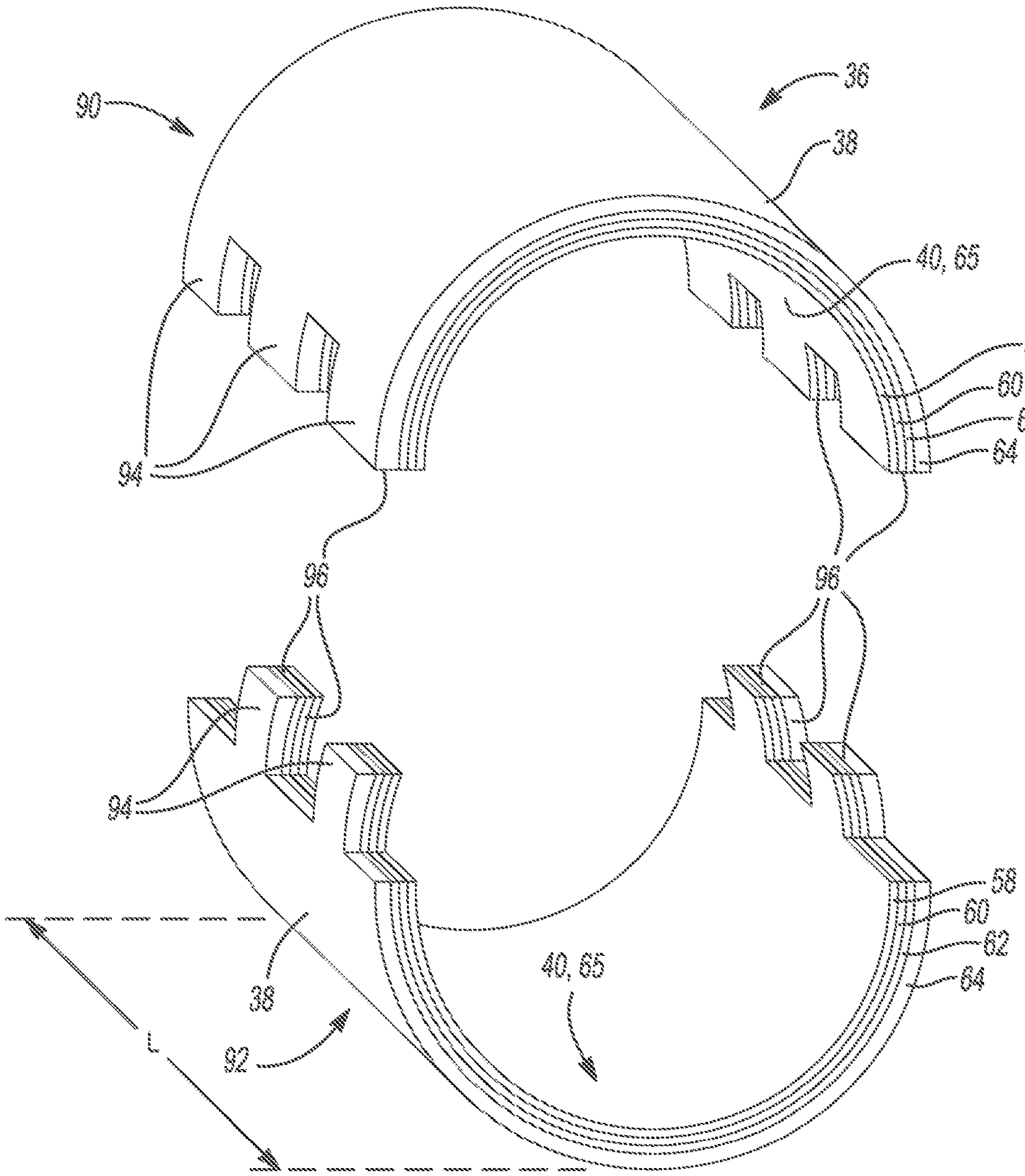


FIG. 4

BEARING WITH VISCO-METAL LAYERS REACTIVE TO INCREASE DYNAMICALLY CLEARANCE AND MINIMUM OIL FILM THICKNESS

INTRODUCTION

The statements in this section merely provide background information relating to the present disclosure, and may not constitute prior art.

The present disclosure relates to motor vehicles, and more specifically to high-load rotating components within motor vehicle powertrains. Rotating masses within motor vehicle internal combustion engines are subject to significant stresses as the rotating components of the engines operate. In particular, in typical internal combustion engines (ICEs), linear motions of pistons in cylinder bores is converted into rotational motion of a crankshaft by way of a series of bearings connecting each of the pistons to a connecting rod, and connecting the connecting rod to the crankshaft. Moreover, the crankshaft rotates within a series of crankshaft or main bearings. Each of the bearings is lubricated to prevent thermal stress and strain, and to reduce frictional losses. However, the loading of a bearing in an ICE is generally not homogenous. That is, as the reciprocating pistons move within the cylinder bores, the loads transferred to the crankshaft via the connecting rods are non-homogeneous. As a result, while typical bearings operate for their intended purpose in ICEs, there is a need in the art for new and improved bearings that increment or enlarge an oil film thickness and provide additional lubrication in areas within the bearing that experience increased load relative to other areas of the bearing, thereby increasing reliability and longevity of the ICE, while reducing repair and manufacturing costs and improving fuel economy of the ICE by way of reduced internal friction.

SUMMARY

According to several aspects of the present disclosure a bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine includes a plurality of bearing portions joined together and forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component. A lubricating fluid is supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component. The bearing having a plurality of bearing layers unevenly distributed about a circumference and along a longitudinal axis of the bearing, and the bearing layers reactively ovalize and alter a minimum lubricating fluid thickness on a portion of the substantially cylindrical central bore that ovalizes in response to transient local loads imparted by the non-homogeneously or homogeneously loaded rotating component.

In another aspect of the present disclosure the plurality of bearing portions include a first or lower bearing portion joined to a second or upper bearing portion, the plurality of bearing layers further including a first bearing layer disposed radially inward of and overtop a second bearing layer, the second bearing layer disposed radially inward of and overtop a third bearing layer, the third bearing layer disposed radially inward of and overtop a fourth bearing layer.

In yet another aspect of the present disclosure the first bearing layer includes a coating layer forming the substantially cylindrical central bore, the coating layer directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component.

In yet another aspect of the present disclosure the second bearing layer includes one or more hard viscoplastic or viscoelastic material and a metal insert or metal layer.

In yet another aspect of the present disclosure the third bearing layer includes one or more hard viscoplastic or viscoelastic material, and is unevenly distributed about the circumference and along the longitudinal axis of the bearing, and wherein the third bearing layer has a non-uniform thickness.

In yet another aspect of the present disclosure the third bearing layer includes a plurality of thickened smooth lobate areas at predetermined locations of peak transient load.

In yet another aspect of the present disclosure the fourth bearing layer includes a metallic bearing substrate, the metallic bearing substrate forming the substantially cylindrical outer surface, the metallic bearing substrate unevenly distributed about the circumference and along the longitudinal axis of the bearing, the fourth bearing layer having a non-uniform thickness, and the fourth bearing layer having a plurality of wells receiving the plurality of thickened smooth lobate areas.

In yet another aspect of the present disclosure in combination, the third bearing layer and the fourth bearing layer have a substantially cylindrical shape.

In yet another aspect of the present disclosure the reactively ovalizing bearing layers increase a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing.

In yet another aspect of the present disclosure the increased clearance further includes a localized increased minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

In yet another aspect of the present disclosure a multi-layer bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine includes a first or upper bearing portion joined to a second or lower bearing portion, the first and second bearing portions forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component. A lubricating fluid is supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component. The multi-layer bearing having a first bearing layer disposed radially inward of and overtop a second bearing layer, the second bearing layer disposed radially inward of and overtop a third bearing layer, the third bearing layer disposed radially inward of and overtop a fourth bearing layer, at least two of the first, second, third and fourth bearing layers having variable thicknesses distributed unevenly about a circumference and along a longitudinal axis of the multi-layer bearing; wherein the variable thicknesses of the at least two of the first, second, third, and fourth bearing layers reactively locally ovalize and alter a minimum lubricating fluid thickness on a portion of the substantially cylindrical central bore that ovalizes in response to transient loads imparted by the non-homogeneously or homogeneously loaded rotating component.

In yet another aspect of the present disclosure the first or upper bearing layer includes a metallic coating or spray powder multi-chemical component coating layer forming the substantially cylindrical central bore, the coating layer directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component.

In yet another aspect of the present disclosure the second or lower bearing layer includes one or more hard viscoplastic or viscoelastic material and a metal insert or metal layer.

In yet another aspect of the present disclosure the third bearing layer includes one or more hard viscoplastic or viscoelastic materials unevenly distributed about the circumference and along the longitudinal axis of the bearing.

In yet another aspect of the present disclosure the third bearing layer includes a plurality of thickened smooth lobate areas at predetermined locations of peak transient load.

In yet another aspect of the present disclosure the fourth bearing layer includes a metallic bearing substrate, the metallic bearing substrate forming the substantially cylindrical outer surface, the metallic bearing substrate unevenly distributed about the circumference and along the longitudinal axis of the bearing and the fourth bearing layer having a plurality of wells receiving the plurality of thickened smooth lobate areas at the predetermined locations of peak load.

In yet another aspect of the present disclosure in combination, the third bearing layer and the fourth bearing layer have a substantially cylindrical shape.

In yet another aspect of the present disclosure the reactively ovalizing bearing layers increase a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing.

In yet another aspect of the present disclosure the increased clearance further includes a localized increased minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

In yet another aspect of the present disclosure a multi-layer bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine includes a first or upper bearing portion joined to a second or lower bearing portion, the first or upper and second or lower bearing portions forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component, and a plurality of bearing layers. A lubricating fluid is supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component. A first of the plurality of bearing layers being a metallic coating or spray powder multi-chemical component coating bearing layer forming the substantially cylindrical bore, directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component, and the first metallic coating or spray powder multi-chemical component coating bearing layer disposed radially inward of and overtop a second of the plurality of bearing layers. The second of the plurality of bearing layers composed of one or more hard viscoplastic or viscoelastic material and a metal insert, the second of the plurality of bearing layers disposed radially inward of and overtop a third of the plurality of bearing layers. The third of the plurality of bearing layers composed of one or more hard viscoplastic or viscoelastic materials, the third of the plurality of bearing layers disposed radially inward of and overtop a fourth of the plurality of bearing layers. The fourth bearing layer including a metallic bearing substrate forming the substantially cylindrical outer surface of the bearing. At least two of the plurality of bearing layers having variable thicknesses distributed unevenly about a circumference and along a longitudinal axis of the multi-layer bearing. One of the at least two of the plurality of bearing layers has a plurality of thickened smooth lobate areas at predetermined locations of peak transient load. Another of the at least two of the plurality of bearing layers has a plurality of wells receiving the plurality of thickened smooth lobate areas at the predetermined locations of peak load, the variable thicknesses of the at least two of the plurality of bearing layers reactively ovalizing in response to transient local loads imparted by the non-homogeneously or homogeneously loaded rotating component, and the reactively ovalizing bearing layers increasing a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing and increase minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. **1** is an environmental view of a motor vehicle equipped with an internal combustion engine having one or more bearings with visco-metallic layers reactive to dynamically increase clearance and minimum oil thickness according to an aspect of the present disclosure;

FIG. **2**A is a plan view of a bearing showing exemplary load patterns at a first crankshaft position according to an aspect of the present disclosure;

FIG. **2**B is a plan view of a bearing showing exemplary load patterns at a second crankshaft position according to an aspect of the present disclosure;

FIG. **2**C is a plan view of a bearing showing exemplary load patterns at a third crankshaft position according to an aspect of the present disclosure;

FIG. **3**A is a plan view of a bearing according to an aspect of the present disclosure;

FIG. **3**B is a cross sectional view taken across line C-C of the bearing of FIG. **3**A according to an aspect of the present disclosure;

FIG. **4** is an axonometric view of the bearing of FIG. **3**A according to an aspect of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to several embodiments of the disclosure that are illustrated in accompanying drawings. Whenever possible, the same or similar reference numerals are used in the drawings and the description to refer to the same or like parts or steps. The drawings are in simplified form and are not to precise scale. For purposes of convenience and clarity, directional terms such as top, bottom, left, right, up, over, above, below, beneath, rear, and front, may be used with respect to the drawings. These and similar directional terms are not to be construed to limit the scope of the disclosure.

Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises", "includes," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

When an element or layer is referred to as being "on," "engaged to," "connected to," or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Although 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 only 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 of the example embodiments.

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.

The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses.

Referring to FIGS. **1** through **2**C, a motor vehicle having a bearing with visco-metallic layers reactive to dynamically increase clearance and minimum oil thickness is shown and generally indicated by reference number **10**. While the motor vehicle **10** is depicted as a car, it should be understood that the motor vehicle **10** may be a car, a truck, an SUV, a van, a motor home, a semi, a tractor, a bus, a go-kart, or any other such motor vehicle **10** without departing from the scope or intent of the present disclosure. The motor vehicle **10** is equipped with a powertrain **12** having an engine **14**, and a transmission **16** operable to translate power from the engine **14** into drive motion. In several aspects, the engine **14** is an internal combustion engine (ICE). While the motor vehicle **10** powertrain **12** of FIG. **1** is depicted as having only an ICE **14** and a transmission **16**, it should be appreciated that the powertrain **12** may include hybrid systems such as battery packs (not shown), electric motors (not shown), or the like without departing from the scope or intent of the present disclosure. The ICE **14** includes a variety of reciprocating and rotating components that operate to translate energy released by combustion of fuel and air within a combustion chamber **18** of the ICE **14** combustion energy into rotational motion. In one example, the ICE **14** includes a crankshaft **20** rotatingly supported in an engine block **22** of the ICE **14** by a first or main bearing (not specifically shown), and rotatingly connected at a crank arm **25** to a connecting rod **26** via a second or connecting rod bearing **28**. The connecting rod **26** is rotatingly connected via a third bearing or piston pin carrier **30** carrying a piston pin, gudgeon pin, or wrist pin **31** to a piston **32** disposed in a cylinder bore **34** of the ICE **14**. In one aspect, the piston **32** moves in a linear fashion through a portion of the cylinder bore **34**. Linear motion of the piston **32** is translated into rotational motion of the crankshaft **20** via the first and second bearings **28**, **30** in conjunction with the connecting rod **26**. The second bearing **28** usually is composed of an "upper connecting rod bearing" **28**A and "lower connecting rod bearing" **28**B: both upper bearing **28**A and lower bearing **28**B can be fixed to or installed in the connecting rod **26** with limited mutual movement. Upper bearing **28**A and lower bearing **28**B participate to create a cylindrical surface surrounded the crankshaft.

The ICE **14** operates in either two or four-stroke manner. That is, in a first example, the ICE **14** is a two stroke engine **14** in which the end of a combustion stroke and the beginning of a compression stroke occur simultaneously, and an intake and exhaust or scavenging stroke occur simultaneously. In the first example, a single rotation of the crankshaft **20** allows a full combustion cycle for a given piston **32**. In a second example, the ICE **14** is a four-stroke engine **14** in which each of an intake, compression, combustion, and exhaust stroke are separated from one another. That is, during the intake stroke, the piston **32** moves towards the crankshaft **20** within the cylinder bore **34**, drawing a mixture of fuel and air into the cylinder bore **34** via an intake port or valve (not specifically shown). During the compression stroke, the piston **32** reverses direction from the intake stroke, moving away from the crankshaft **20**, and compressing the fuel and air mixture. During the combustion stroke, the fuel and air mixture is ignited within the cylinder bore **34** causing an increase in pressure within that drives the piston **32** back towards the crankshaft **20** again. During the exhaust stroke, the piston **32** reverses direction again and moves away from the crankshaft **20**, thereby pushing exhaust material out of the cylinder bore **34** via an exhaust port or valve (not specifically shown). In the second example, two full rotations of the crankshaft **20** are required for a full combustion cycle for a given piston **32**. In a third example, the ICE **14** is a rotary engine such as a Wankel-type engine (not specifically shown). In a Wankel-type engine, rather than having linearly reciprocating pistons **32**, the ICE **14** includes a substantially triangular rotary piston or rotor (not shown) that rotates eccentrically via a toothed gear-like interface about a central eccentric shaft or E-shaft. In some examples, Wankel-type engines operate as two stroke engines **14**, while in other examples, Wankel-type engines operate as four-stroke engines **14**. However, each of the first, second, and third examples, the crankshaft **20** and the E-shaft rotate within and are supported by first bearings **24**. First bearing **24** support the shaft in the cylinder block **22** and is usually called "main bearing". Moreover, in each of the first, second, and third examples, loads on the first bearings **24** vary as the pistons **32** or the rotor reciprocate within the ICE **14**.

Turning now to FIGS. **2**A-**2**C specifically, and with continuing reference to FIG. **1**, in several aspects, the second or connecting rod bearing **28** experiences inconsistent load as a piston **32** of the ICE **14** moves within the ICE **14**. In the example of FIGS. **2**A-**2**C, the second or connecting rod bearing **28** is shown as a part of a four-stroke ICE **14** having pistons **32** linearly reciprocating within cylinder bores **34**. Each of first and second bearings **24**, **28** is subjected to periodic compression stresses as the ICE **14** operates. The connecting rod **26** of FIG. **2**A is shown just before achieving top dead center (TDC) in a maximum compressive load at the peak of combustion. That is, the connecting rod **26** and the piston **32** are disposed as far away from an axis of rotation "A" of the crankshaft **20**. In the TDC position, during a compression stroke, the piston **32** moves to the top-most position within the cylinder bore **34**, thereby compressing an air/fuel mixture within a combustion chamber of the cylinder bore **34**. In FIG. **2**A, the TDC position places peak compressive load "L1" on the second bearing **28**, on upper portion **28**A at locations approximately within −45° and 45° displaced from the longitudinal axis "B" of the connecting rod **26**. The longitudinal axis B is defined as the axis that starts from a center of a first substantially cylindrical aperture **48** within a big end **50** of the connecting rod **26** and extends to a center of a second substantially cylindrical aperture **52** disposed in a small end **54** of the connecting rod **26**.

In the example of FIG. **2**B, the connecting rod **26** is shown in a second position in which the second bearing **28** experiences a max inertial or tension load. In the second position, the connecting rod **26** is shown at TDC just as the piston **32** is about to begin descending towards the crankshaft **20** during the combustion stroke. As the piston **32** begins the combustion stroke, expanding gasses from combustion of fuel and air force the piston **32** towards the crankshaft **20**. However, at the very peak of the travel of the piston **32**, that is, at TDC, peak inertial loads "L2" are transmitted through the piston **32** to the connecting rod **26** and into the second bearing **28** on lower bearing portion **28**B at locations approximately between 135° and 225° displaced from the longitudinal axis "B" of the connecting rod **26**, as shown in FIG. **2**B.

In the example of FIG. **2**C, the connecting rod **26** is shown in a third position in which the second bearing **28** experiences a maximum lateral loading. In the third position, the connecting rod **26** is shown at maximum engine **14** speed when the crank arm **25** direction is substantially perpendicular to the longitudinal axis "B" of the connecting rod **26**. In the third position, the second bearing **28** is loaded substantially on upper bearing **28**A, at 45° to the longitudinal axis "B" of the connecting rod **26**.

In each of FIGS. **2**A-**2**C, the second bearing **28** experiences maximum load at specific rotational positions of the crankshaft **20** and connecting rod **26**. The maximum loads may vary substantially with respect to the particular ICE **14** application, and location within the particular ICE **14**. In some aspects, the maximum transient loads and peaks loads during a rotation of crankshaft vary relative to the angular velocity of the engine and depending by the combustion and the engine working conditions. Additionally, while only three positions have thus far been described, it should be appreciated that depending on the type of ICE **14**, the directionality and the locations of the maximum bearing loads may vary substantially. Additionally, while the foregoing descriptions of FIGS. **2**A-**2**C have focused substantially on the loading of the second or connecting rod bearing **28**, it should be appreciated that similar stresses and/or loads are experienced by other components of the ICE **14**, including both the first and third bearings **24**, **30**. Because the first, second, and third bearings **24**, **28**, **30** each experience inconsistent loads as the ICE **14** operates, it is desirable to provide the first, second, and/or third bearings **24**, **28**, **30** additional lubrication and/or support in areas that are exposed to high loads. While in the foregoing, the first, second, and third bearings **24**, **28**, **30** have been described as having a single or two part construction, e.g. lower and upper bearing portions **28**A and **28**B, it should be appreciated that each of the bearings **24**, **28**, **30** may be constructed of more than two bearing portions without departing from the scope or intent of the present disclosure.

Turning now to FIG. **3**A, and with continuing reference to FIGS. **1**-**2**C a bearing **36** according to one or more of the first, second, or third bearings **24**, **28**, **30** is shown in plan view supporting a shaft **37** of an engine part. The bearing **36** has a substantially cylindrical outer surface **38** and defines a substantially cylindrical central bore **40**. The substantially cylindrical outer surface **38** is sized and shaped to engage with and fit within a substantially cylindrical carrier **42**. In the example of an engine block, the first bearing **24** fits into a substantially cylindrical carrier **42** defined by a main bearing cap and main bearing seat (not specifically shown) while in the example of the second or connecting rod bearing **28**, the substantially cylindrical outer surface **38** fits within a cylindrical aperture **48** in a big end **50** of the connecting rod **26**. In the example of the third bearing or piston pin carrier **30**, the substantially cylindrical outer surface **38** fits within a second substantially cylindrical aperture **52** disposed within a small end **54** of the connecting rod **26**. The substantially cylindrical central bore **40** of the bearing **36** carries an inconsistently loaded part **37**. In a first example, the substantially cylindrical central bore **40** of the first bearing **24** fits around and rotates about a portion of the crankshaft **20**. In a second example, the substantially cylindrical central bore **40** of the second bearing **28** fits around and rotates about the crank pin or rod journal **56** at a distal end of the crank arm **25** of the crankshaft **20**. In a third example, the substantially cylindrical central bore **40** of the third bearing **30** fits around and rotates about the piston pin, gudgeon pin, or wrist pin **31**. The third bearing **30** fits within the small end **54** of the connecting rod **26**, and can be called "small end bushing". In still further aspects, a fourth bearing fits within the piston **32** and supports the piston wrist pin **31**. That is, in some examples, the wrist pin **31** is rotatably supported within both the small end **54** of the connecting rod **26** and within the piston **32** by third bearing **30** or small end bushing.

Because of the reciprocating nature of the motion of the pistons **32** within the engine **14**, loads carried by each of the first, second, and third bearings **24**, **28**, **30** are non-homogeneous, as described with respect to FIGS. **2A-2C**. As a result of the non-homogeneous loads imparted to the first, second, and third bearings **24**, **28**, **30**, it is advantageous to provide lubrication to each of the bearings **24**, **28**, **30** to prevent unnecessary and undesirable heat and frictional wear. Therefore, in several aspects, some or all of the first, second and third bearings **24**, **28**, **30** have a multi-layer construction, as shown in the bearing **36** of FIG. **3A**. In some examples, the multi-layer construction of the bearing **36** includes a first or coating layer **58**. In some aspects, the first layer **58** is composed of a metal or metal alloy such as bronze, brass, tin compounds, or the like, having desirable friction and wear characteristics. The first or coating layer **58** is disposed overtop and concentrically inward of a second or hard viscoplastic/viscoelastic material and metal insert/layer **60**. In several aspects, the second layer **60** is composed of a viscoelastic material having desirable stiffness, compression resistance, resiliency, and the like. The second layer **60** is disposed concentrically inward and overtop a third or hard viscoplastic or viscoelastic material layer **62**. In some aspects, the third layer **62** is composed of a polyetherketone, or a thermoplastic, viscoplastic or viscoelastic material. In some aspects, the material of the third layer **62** is mixed with carbon, such as graphite. The hard viscoplastic or viscoelastic material **62** is disposed concentrically inward and overtop of a fourth metallic or steel bearing substrate **64** layer.

With respect to the second and third layers **60**, **62** in particular, each of the second and third layers **60**, **62** is a thin metal layer in combination with a viscoplastic layer or a thin metal layer coated directly in viscoplastic material. In several aspects, at least a viscoplastic layer in the second and third layers **60**, **62** are reactive, ovalizing and opening increased clearance for the engine part **31**, loaded by oil pressure, when and where there is more fluid load due to reactions of the viscoplastic/viscoelastic material making up the second and third layers **60**, **62**. The dynamic change of curvature of an inner support surface **65** of the bearing **36** is dependent on the properties of the viscoplastic/viscoelastic material. That is, the dynamic change of curvature of the inner support surface **65** of the bearing is dependent on the limit of elasticity to ovalization, and a viscoplastic/viscoelastic radial layer reaction limit for each of the second and third layers **60**, **62**. Higher minimum oil film thickness or fluid lubricating film thickness caused by higher clearances, i.e. local increased eccentricity due to ovalization of the multilayer bearing **36**, is induced by load reactive bearing **36** layers locally on loaded oil or lubricating fluid film thickness of a given sector of the bearing **36** support surface **65**. The oil or fluid film thickness forms an enlarged pillow providing increased support and lubrication to the engine part **31** supported by the bearing **36** as distributed film thickness loads are increased. In other words, by locally ovalizing both in circumferential and an axial or longitudinal aspect, the bearing **36** provides a pathway for lubricant to enter areas of the bearing **36** that are experiencing increased load. Thus, increased lubrication is provided at times and locations where the bearing **36** and engine part **31** are most prone to wear. Moreover, in a more homogeneously loaded bearing **36**, the axial or longitudinal loading of the bearing **36** can be mitigated by providing localized ovalization that generates a higher lubricant film thickness or pillow that reactively allows additional lubricant to enter and better lubricate the support surface **65** of the bearing **36** where it contacts the engine part **31**.

In several aspects, the third or hard viscoplastic or viscoelastic material layer **62** and the fourth metallic or steel bearing substrate layer **64** each have a variable thickness which will be described in greater detail below. However, in combination, the third and fourth layers, **62**, **64** form a substantially cylindrical shape. The third layer **62** includes four substantially smooth lobate protrusions or areas **66**, **68**, **70**, **72** protruding into and received by wells **74**, **76**, **78**, **80** within the fourth layer **64**. In several aspects, the circumferential locations of the smooth lobate areas **66**, **68**, **70**, and **72** and the corresponding wells **74**, **76**, **78**, **80** are defined by predetermined locations of non-homogeneous transient peak loads experienced by the bearing **36**. The placement of the lobate areas **66**, **68**, **70**, **72** and the wells **74**, **76**, **78**, **80** is optimized to improve oil film thickness and to improve oil film distribution to reduce wear of the bearing **36** and an engine **14** supported by the bearing **36**. That is, in order to provide increased support and/or lubrication for the bearing **36** at predetermined locations where the bearing **36** experiences transient peak loads, wells are formed in the metallic or steel bearing substrate. In some aspects, annular or circumferential aspects the smooth lobate areas **66**, **68**, **70**, **72**, and the wells **74**, **76**, **78**, **80** have a substantially continuous smooth shape optimized to reduce friction and improve lubrication of a part **37** supported by the bearing **36**. While the smooth lobate protrusions **66**, **68**, **70**, **72** and the wells **74**, **76**, **78**, **80** are shown symmetrically disposed about the circumference of the bearing **36**, it should be understood that the lobate protrusions **66**, **68**, **70**, **72** and wells **74**, **76**, **78**, **80** need not necessarily be symmetrically disposed about the circumference of the bearing **36**. However, as many ICEs **14** use similarly-sized bearings **36** in conjunction with various non-homogeneously loaded rotating components, in some instances, it is desirable to have such symmetry. For example, while the peak loads "L1", "L2", and "L3" shown in FIGS. **2A-2C** are shown in approximately even distribution around the bearing **36**, in some ICE **14** types, the locations of transient peak loads may vary, and thus, the locations of the smooth lobate protrusions **66**, **68**, **70**, **72**, and corresponding wells **74**, **76**, **78**, **80** must likewise vary. Additionally, by producing symmetrical bearings **36**, the same bearings **36** may be used in a variety of different ICE **14** types and orientations, thereby reducing overall engineering, production, and parts costs. Moreover, because certain ICE **14** types, such as V-engines, boxer engines, and the like, produce ambidextrous load on the crankshaft **20**, symmetrical multi-layer bearings **36** are advantageous, as loads are applied from bilaterally, rather than generally from a single side as in an inline engine configuration.

Turning now to FIG. **3B**, and with continuing reference to FIGS. **1-3A**, a cross section taken across line C-C of the bearing **36** of FIG. **3A** is shown. In some examples, in order to reduce a potential for the multi-layer construction of the bearing **36** from experiencing longitudinal slippage, to ensure that the bearing **36** remains stable, and to prevent the bearing **36** from imparting skewed support for the engine part **31** that the bearing supports **36** the lobate areas **66**, **68**, **70**, **72**, and the wells **74**, **76**, **78**, **80** are limited in extent. That is in a first example, the lobate areas **66**, **68**, **70**, **72**, and the wells **74**, **76**, **78**, **80** extend for only a portion of a total length

"L" of the bearing **36**. In a second example, the lobate areas **66**, **68**, **70**, **72**, and the wells **74**, **76**, **78**, **80** extend for the total length "L" of the bearing **36**. As shown in FIG. **3**B, in both the first and second examples, along an axial aspect of the bearing **36**, the smooth lobate areas **66**, **70**, and wells **74**, **78** have a discontinuous shape. That is, the wells **74**, **78** in the metallic or steel bearing substrate **64** have angular or beveled flange areas **82** extending to a well bottom **84**. Likewise, the smooth lobate areas **66**, **70** fit concentrically within the metallic or steel bearing substrate **64** and have matching beveled flange areas **86** and a lobate outer portion **88** disposed within and in contact with the wells **74**, **78**. While only the smooth lobate areas **66**, **70** and wells **74**, **78** are shown in FIG. **3**B, it should be appreciated that the smooth lobate areas **68**, **72** and wells **76**, **80** of FIG. **3**A are constructed to have substantially the same topography. Moreover, it should be understood that while the lobate areas **66**, **70**, and the wells **74**, **78** have been shown and described as having angular, or beveled, discontinuous axial shapes, each of the lobate areas **66**, **68**, **70**, **72** and the wells **74**, **76**, **78**, **80** may have other continuous, or discontinuous shapes without departing from the scope or intent of the present disclosure. In an example, depending on the size, shape, and non-homogeneous loading characteristics of a given engine part **31**, each of the smooth lobate areas **64**, **66**, **68**, **70**, and each of the wells, **74**, **76**, **78**, **80** have longitudinal section of layers that can be trapezoidal, with multi lobate areas, or of other shapes along the cylindrical bearing axis, creating three-dimensional continuous shape approximating a longitudinal half of one or more quenelles for example.

Additionally, while in the foregoing description, the bearing **36** has been described as having four layers (namely the coating **58**, viscoplastic/viscoelastic and metal insert/layer **60**, the hard viscoelastic or viscoplastic material **62**, and the metallic or steel bearing substrate **64**), it should be appreciated that the bearing **36** may include a greater number of layers, or fewer layers, depending on the design constraints and needs of a particular application.

Turning now to FIG. **4**, and with continued reference to FIGS. **1**-**3**B, a multi-layer bearing **36** according to the present disclosure is shown in axonometric form so that the construction of the bearing **36** can be better understood. In several aspects, the multi-layer bearing **36** is composed of two separate halves, namely a first or upper half **90**, and a second or lower half **92**. The upper and lower halves **90**, **92** have interlocking teeth **94**. While in the diagram of FIG. **4** the interlocking teeth **94** are shown as having a shape substantially like a square wave or a series of substantially rectangular crenellations, it should be understood that the interlocking teeth **94** may take other forms without departing from the scope or intent of the present disclosure. For example, the interlocking teeth **94** may have a curvilinear or substantially sinusoidal shape, a sawtooth shape, a triangular shape, or the like. The interlocking teeth **94** are located around the bearing **36** so that a joint area **96** between the interlocking teeth **94** of the upper half **90** and the interlocking teeth **94** of the lower half **92** allow ovalization or change of the overall cylindrical shape of the inner support surface **65** of the bearing **36** as the bearing **36** experiences non-homogeneous loads.

While in the foregoing description, the bearings **36** have been described with respect to various rotating components within an ICE **14**, it should be appreciated that similar bearings **36** may be used in other applications within a motor vehicle **10**, or in other applications entirely. That is, the bearings **36** may be used to support and provide lubrication to any rotating component within an ICE **14**, such as a crankshaft **20**, camshaft (not shown), or any other such shaft in rotational motion in an ICE **14**. More generally, the bearings **36** may be used to support and provide lubrication to any rotating mechanism or shaft without departing from the scope or intent of the present disclosure.

A bearing **36** with visco-metallic layers dynamically reactive to increase clearance and minimum oil film thickness or fluid lubricating film thickness offers several advantages. These include incrementing or enlarging an oil film thickness and providing additional lubrication in areas within the bearing that experience increased load relative to other areas of the bearing, thereby increasing reliability and longevity of the ICE **14**, while reducing repair and manufacturing costs and improving fuel economy of the ICE **14** by way of reduced internal friction

The description of the present disclosure is merely exemplary in nature and variations that do not depart from the gist of the present disclosure are intended to be within the scope of the present disclosure. Such variations are not to be regarded as a departure from the spirit and scope of the present disclosure.

What is claimed is:

1. A bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine comprises:

a plurality of bearing portions joined together and forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component;

a lubricating fluid supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component;

the bearing having a plurality of bearing layers unevenly distributed about a circumference and along a longitudinal axis of the bearing;

wherein the bearing layers reactively ovalize and alter a minimum lubricating fluid thickness on a portion of the substantially cylindrical central bore that ovalizes in response to transient local loads imparted by the non-homogeneously or homogeneously loaded rotating component.

2. The bearing of claim **1** wherein the plurality of bearing portions include a first or lower bearing portion joined to a second or upper bearing portion, the plurality of bearing layers further comprising a first bearing layer disposed radially inward of and overtop a second bearing layer, the second bearing layer disposed radially inward of and overtop a third bearing layer, the third bearing layer disposed radially inward of and overtop a fourth bearing layer.

3. The bearing of claim **2** wherein the first bearing layer comprises a coating layer forming the substantially cylindrical central bore, the coating layer directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component.

4. The bearing of claim **2** wherein the second bearing layer comprises one or more hard viscoplastic or viscoelastic material and a metal insert or metal layer.

5. The bearing of claim **2** wherein the third bearing layer comprises one or more hard viscoplastic or viscoelastic material, and is unevenly distributed about the circumference and along the longitudinal axis of the bearing, and wherein the third bearing layer has a non-uniform thickness.

6. The bearing of claim 5 wherein the third bearing layer comprises a plurality of thickened smooth lobate areas at predetermined locations of peak transient load.

7. The bearing of claim 6 wherein the fourth bearing layer comprises a metallic bearing substrate, the metallic bearing substrate forming the substantially cylindrical outer surface, the metallic bearing substrate unevenly distributed about the circumference and along the longitudinal axis of the bearing, the fourth bearing layer having a non-uniform thickness, and the fourth bearing layer having a plurality of wells receiving the plurality of thickened smooth lobate areas.

8. The bearing of claim 2 wherein in combination, the third bearing layer and the fourth bearing layer have a substantially cylindrical shape.

9. The bearing of claim 1 wherein the reactively ovalizing bearing layers increase a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing.

10. The bearing of claim 9 wherein the increased clearance further comprises a localized increased minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

11. A multi-layer bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine comprises:

a first or upper bearing portion joined to a second or lower bearing portion, the first and second bearing portions forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component;

a lubricating fluid supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component;

the multi-layer bearing having a first bearing layer disposed radially inward of and overtop a second bearing layer, the second bearing layer disposed radially inward of and overtop a third bearing layer, the third bearing layer disposed radially inward of and overtop a fourth bearing layer, at least two of the first, second, third and fourth bearing layers having variable thicknesses distributed unevenly about a circumference and along a longitudinal axis of the multi-layer bearing; wherein the variable thicknesses of the at least two of the first, second, third, and fourth bearing layers reactively locally ovalize and alter a minimum lubricating fluid thickness on a portion of the substantially cylindrical central bore that ovalizes in response to transient loads imparted by the non-homogeneously or homogeneously loaded rotating component.

12. The bearing of claim 11 wherein the first or upper bearing layer comprises a metallic coating or spray powder multi-chemical component coating layer forming the substantially cylindrical central bore, the coating layer directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component.

13. The bearing of claim 11 wherein the second or lower bearing layer comprises one or more hard viscoplastic or viscoelastic material and a metal insert or metal layer.

14. The bearing of claim 11 wherein the third bearing layer comprises one or more hard viscoplastic or viscoelastic material unevenly distributed about the circumference and along the longitudinal axis of the bearing.

15. The bearing of claim 11 wherein the third bearing layer comprises a plurality of thickened smooth lobate areas at predetermined locations of peak transient load.

16. The bearing of claim 15 wherein the fourth bearing layer comprises a metallic bearing substrate, the metallic bearing substrate forming the substantially cylindrical outer surface, the metallic bearing substrate unevenly distributed about the circumference and along the longitudinal axis of the bearing and the fourth bearing layer having a plurality of wells receiving the plurality of thickened smooth lobate areas at the predetermined locations of peak load.

17. The bearing of claim 11 wherein in combination, the third bearing layer and the fourth bearing layer have a substantially cylindrical shape.

18. The bearing of claim 11 wherein the reactively ovalizing bearing layers increase a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing.

19. The bearing of claim 18 wherein the increased clearance further comprises a localized increased minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

20. A multi-layer bearing supporting a non-homogeneously or homogeneously loaded rotating component of a motor vehicle engine comprises:

a first or upper bearing portion joined to a second or lower bearing portion, the first or upper and second or lower bearing portions forming a substantially cylindrical outer surface and a substantially cylindrical center bore, the substantially cylindrical central bore surrounding and supporting the non-homogeneously or homogeneously loaded rotating component;

a lubricating fluid supplied to the multi-layer bearing and forming a lubricating film between the substantially cylindrical central bore and the non-homogeneously or homogeneously loaded rotating component;

a plurality of bearing layers;

a first of the plurality of bearing layers being a metallic coating or spray powder multi-chemical component coating bearing layer forming the substantially cylindrical bore, directly supporting and in contact with the non-homogeneously or homogeneously loaded rotating component, and the first metallic coating or spray powder multi-chemical component coating bearing layer disposed radially inward of and overtop a second of the plurality of bearing layers;

the second of the plurality of bearing layers composed of one or more hard viscoplastic or viscoelastic material and a metal insert, the second of the plurality of bearing layers disposed radially inward of and overtop a third of the plurality of bearing layers;

the third of the plurality of bearing layers composed of one or more hard viscoplastic or viscoelastic material, the third of the plurality of bearing layers disposed radially inward of and overtop a fourth of the plurality of bearing layers;

the fourth bearing layer including a steel bearing substrate forming the substantially cylindrical outer surface of the bearing; and

at least two of the plurality of bearing layers having variable thicknesses distributed unevenly about a circumference and along a longitudinal axis of the multi-layer bearing, one of the at least two of the plurality of bearing layers having a plurality of thickened smooth lobate areas at predetermined locations of peak transient load, another of the at least two of the plurality of bearing layers having a plurality of wells receiving the plurality of thickened smooth lobate areas at the predetermined locations of peak load, the variable thicknesses of the at least two of the plurality of bearing layers reactively ovalizing in response to transient local loads imparted by the non-homogeneously or homogeneously loaded rotating component, and the reactively ovalizing bearing layers increasing a clearance at predetermined locations about the circumference and along the longitudinal axis of the bearing and increase minimum oil film thickness or fluid lubricating film thickness at the predetermined locations about the circumference and along the longitudinal axis of the bearing.

* * * * *