



- (51) International Patent Classification:
F01L 1/12 (2006.01) *F01L 1/18* (2006.01)
- (21) International Application Number:
PCT/US2014/027954
- (22) International Filing Date:
14 March 2014 (14.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/789,036 15 March 2013 (15.03.2013) US
- (71) Applicant: **ROLLER BEARING COMPANY OF AMERICA, INC.** [US/US]; One Tribology Center, Oxford, Connecticut 06478 (US).
- (72) Inventors: **SMITH, Kelvin**; 224 Bruning Road, New Hartford, Connecticut 06057 (US). **BLAUNER, Brett**; 2854 Bonita Drive, Valparaiso, Indiana 46385 (US).
- (74) Agents: **RISPOLI, Robert L.** et al.; MKG, LLC, 306 Industrial Park Road, Suite 206, Middletown, Connecticut 06457 (US).
- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

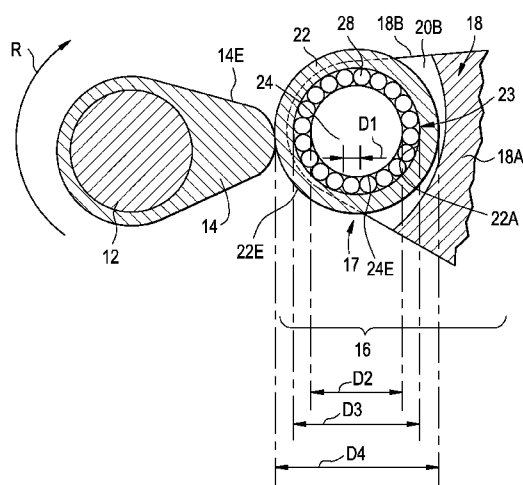
- (84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: NEEDLE ROLLER CAM FOLLOWER FOR HIGHER MILEAGE APPLICATIONS OF LIGHT, MEDIUM AND HEAVY DUTY VEHICLES

FIG. 2



(57) Abstract: A roller assembly for a diesel engine used in a high mileage vehicle includes a roller having an exterior roller surface and an interior surface that defines a bore extending therethrough. A pin is positioned in the bore and defines an exterior pin surface. A plurality of rolling elements is positioned between the exterior pin surface and the roller interior surface. Each of the rolling elements rollingly engages the exterior pin surface and the roller interior surface. The roller assembly defines a clearance of between about 0.01 mm to about 0.03 mm between the rolling elements, the exterior pin surface and the interior surface. The roller assembly is configured to achieve extended life criteria wherein the clearance does not increase to more than 0.02 mm to 0.06 mm after 500,000 miles of travel of a vehicle powered by a diesel engine having the roller assembly installed therein.



**NEEDLE ROLLER CAM FOLLOWER FOR HIGHER MILEAGE APPLICATIONS OF
LIGHT, MEDIUM AND HEAVY DUTY VEHICLES**

FIELD OF THE INVENTION

5 The present invention relates generally to needle roller cam follower bearings, and more particularly to needle roller cam follower bearings for diesel engines used in higher mileage applications of light, medium and heavy duty vehicles.

BACKGROUND OF THE INVENTION

10 Known bearings include various means for guiding and positioning rollers. Bearing types include journal bearings wherein a shaft is rotatably supported by an outer ring. Journal bearings typically require a lubricant (e.g., high pressure oil) to be pumped between and around the shaft and an interior surface defined by the outer ring. Needle roller bearings are another type of bearing. Needle roller bearings have a plurality of cylindrical shaped rolling elements,
15 generally referred to as needles, disposed between the shaft and the interior surface defined by the outer ring. Thus the shaft is rotatably supported by the needles. Needle roller bearings require less lubricant than journal bearings. Needle roller bearings also operate at lower friction levels than comparably sized journal bearings. However, needle roller bearings have higher contact pressures on the shaft at the rolling interface with the needles. Thus the operating life of
20 needle roller bearings is generally less than comparably sized journal bearings. Needle roller bearings are easily contaminated by debris such as byproducts of combustion generated in an engine. Such byproducts are abrasive and can cause wear and premature failure of the needle roller bearing.

25 Roller bearings can be used for reducing friction between components of engines. For example, tappet roller bearings can be incorporated into an engine valve drive mechanism for minimizing friction of the valve drive mechanism components. In general, to reduce friction on an engine and thus reduce fuel consumption, tappet roller bearings are fitted to the mechanism which changes the rotation of a cam shaft synchronized with an engine crank shaft into the reciprocal drive for the intake valve and exhaust valve.

30 Diesel engines such as those used in higher mileage applications of light, medium and heavy duty vehicles typically use journal type bearings in cam follower applications because of

their ability to operate without significant wear for over 250,000 miles to as much as one million miles of operation. However, journal bearings require a pumped supply of high pressure lubricating oil to operate in such applications. There has been a long felt and unfulfilled need for lower friction cam follower bearings for use in such higher mileage applications. However, despite significant efforts, those skilled in the relevant art have been unable to design a needle roller bearing that has a sufficient life suitable for use in diesel engines for such higher mileage applications.

SUMMARY

10 According to aspects illustrated herein there is provided a roller assembly for a diesel engine used in a high mileage vehicle, the roller assembly comprising: a roller having an exterior roller surface and an interior surface that defines a bore extending therethrough; a pin positioned in the bore and defining an exterior pin surface; and a plurality of rolling elements positioned between the exterior pin surface and the interior surface of the roller, each of the plurality of rolling elements rollingly engages the exterior pin surface and the interior surface of the roller; 15 the roller assembly defines a clearance of between about 0.01 mm to about 0.03 mm between the rolling elements, the exterior pin surface and the interior surface; and the roller assembly is configured to achieve extended life criteria for the diesel engines used in the high mileage vehicles, the extended life criteria comprises the clearance not increasing to more than 0.02 mm to 0.06 mm after 500,000 miles of travel of a vehicle powered by a diesel engine having the roller assembly installed therein. 20

According to other aspects illustrated herein there is provided a cam and follower assembly for a diesel engine used in a high mileage commercial vehicle, the cam and follower assembly comprising: a cam mounted on a cam shaft, the cam defining an exterior cam surface; a 25 follower assembly including a housing having a roller assembly rotatably mounted therein; the roller assembly comprising, a roller having an exterior roller surface and an interior surface that defines a bore extending therethrough, the exterior roller surface engaging the exterior cam surface, a pin positioned in the bore and defining an exterior pin surface, and a plurality of rolling elements positioned between the exterior pin surface and the interior surface of the roller, each of the plurality of rolling elements rollingly engages the exterior pin surface and the interior surface of the roller, the roller assembly defines a clearance of between about 0.01 mm to about 30

0.03 mm between the rolling elements, the exterior pin surface and the interior surface, and the roller assembly is configured to achieve extended life criteria for the diesel engines used in the high mileage vehicles, the extended life criteria comprises the clearance not increasing to more than 0.02 mm to 0.06 mm after 500,000 miles of travel of a vehicle powered by a diesel engine
5 having the roller assembly installed therein; and wherein the follower assembly is configured to achieve extended life criteria for diesel engines used in higher mileage vehicles.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional elevation view of a portion of a cam and follower assembly in
10 accordance with one embodiment of the present invention;

FIG. 2 is a cross sectional view of the cam and follower assembly of FIG. 1, taken across
line 2-2;

FIG. 3 is a cross sectional elevation view of a portion of a cam and follower assembly in
accordance with another embodiment of the present invention having a thrust washer; and

15 FIG. 4 is an exploded view of the roller sub-assembly of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

In reference to FIGS. 1, 2 and 4, a cam and follower assembly for use in a large diesel engine such as that used in higher mileage applications of light, medium and heavy duty vehicles
20 is generally designated by the numeral 10. The cam and follower assembly 10 includes a cam shaft 12 with a cam 14 positioned thereon. The cam 14 defines an exterior cam surface 14E which rollingly engages a roller (e.g., cam follower) as described below. The cam and follower assembly 10 includes a follower assembly 16 that is in moving relation to the cam 14. The cam and follower assembly 10 of the present invention is designed and configured for use in large
25 diesel engines installed in Class 1-3 vehicles (i.e., light duty vehicles), Class 4-6 vehicles (i.e., medium duty vehicles), and Class 7-8 vehicles (i.e., heavy duty vehicles).

The follower assembly 16 includes a housing 18 with a roller sub-assembly 17 rotatably positioned therein as described below. A portion of the housing 18 is shown cut off for illustrative purposes. The housing 18 has a base portion 18A and has two prongs 18B and 18C
30 extending from the base portion 18A in a forked configuration. The prongs 18B and 18C are spaced apart from one another thereby defining a gap G therebetween. The gap G is positioned

between an inwardly facing wall 20B of the prong 18B and an inwardly facing wall 20C of the prong 18C. The prong 18B and the prong 18C each have a bore 26 extending therethrough such that the bores 26 are concentric with one another.

As shown in FIGS. 1 and 2, the roller sub-assembly 17 includes a roller 22 (e.g., a cam follower) rotatably mounted on a pin 24 with a plurality of rolling elements 28 rotatably positioned therebetween as described below. Each of the rolling elements 28 defines an outer diameter D1. The pin 24 defines an exterior surface 24E having an outer diameter D2. The roller 22 has a bore 23 therethrough defining an interior surface 22A having an inner diameter D3, also referred to herein as a bore diameter D3. The roller 22 also defines an exterior surface 22E having an outer diameter D4. The plurality of rolling elements 28 rollingly engage the exterior surface 24E defined by the pin 24 and the interior surface 22A defined by the roller 22. The exterior surface 22E defined by the roller 22 rollingly engages the cam surface 14E of the cam 14 to move the housing 18 to open and close intake and exhaust valves (not shown) at timed intervals. Opposing ends of the pin 24 are secured in the bores 26 of each of the prongs 18B and 18C, with suitable means such as by staking, pinning, and the like.

As illustrated in FIG. 1, the roller sub-assembly 17 and the roller 22 included therein extend a width W in an axial direction along an axis L, between a first end face 29B and a second end face 29C defined by the roller 22. During operation, the roller 22 rotates around the pin 24 and thrusts axially along the axis L. Axial movement of the roller 22 is limited by the inwardly facing wall 20B of the prong 18B and the inwardly facing wall 20C of the prong 18C. Thus the first end face 29B slidingly engages the inwardly facing wall 20B of the prong 18B, and the second end face 29C slidingly engages the inwardly facing wall 20C of the prong 18C.

The design of the pin 24, rolling elements 28 and roller 22 is optimized for dynamic load rating and roller bending stress. A roller 22 having a maximum bore diameter D3 maximizes the dynamic load rating of the roller sub-assembly 17. However, the bore diameter D3 is limited by the bending stress in the roller 22 caused by loads applied thereto by the rolling elements 28. The number of rolling elements 28 affects the bending stress in the roller, wherein increasing the number of rolling elements 28 reduces the bending stress. The pin 24 is subject to the highest rolling element contact pressures because there is a diverging contact between the pin 24 and the rolling elements 28. The life of the pin 24 is lowest because the load is stationary with regard to

the pin 24. Abrasive wear and potential spalling of the pin 24 are minimized by use of suitable materials as described herein.

The inventor has discovered that a roller sub-assembly 17 having dimensions and being made from materials described herein is able to achieve extended life criteria for diesel engines used in higher mileage applications of light, medium and heavy duty vehicles powered by diesel engines. In one embodiment, the extended life criteria requires that the clearance of about 0.01 mm to about 0.03 mm between the rolling elements 28, the exterior pin surface 24E and the interior surface 22A does not increase to more than 0.02 mm to 0.06 mm after 250,000 miles of travel of a vehicle powered by a diesel engine having the roller sub-assembly 17 installed therein. In one embodiment, the extended life criteria requires that the clearance of between about 0.01 mm to about 0.03 mm does not increase to more than 0.02 mm to 0.06 mm after 1,000,000 miles of travel of a vehicle powered by a diesel engine having the roller sub-assembly 17 installed therein.

In one embodiment, the extended life criteria requires that the exterior surface 24E of the pin 24 has no spalling, for example, no visible or measureable spalling after 250,000 miles of travel of a vehicle powered by a diesel engine having the roller sub-assembly 17 installed therein. In one embodiment, the extended life criteria requires that the exterior surface 24E of the pin 24 has no spalling, for example, no visible or measureable spalling after 1,000,000 miles of travel of a vehicle powered by a diesel engine having the roller sub-assembly 17 installed therein.

Design of the roller sub-assembly 17 is limited by the internal geometry of the diesel engine. The outer diameter D_4 of the roller 22, and the width W of the roller sub-assembly 17 are fixed. Therefore, the inner diameter D_3 of the roller 22, the outer diameter D_2 of the pin 24 and the outer diameter D_1 of the rolling elements 28 are optimized for all engine geometries, in particular to optimize a radial thickness T (i.e., $(D_4 - D_3)/2$) of the roller 22 (FIG. 1) while the outer diameter D_1 of the rolling elements 28 is optimized in order to increase the capacity/life (e.g., dynamic load rating) of the roller sub-assembly 17. In one embodiment, the radial thickness T is between about one to two times the outer diameter D_1 of the rolling elements 28.

The inventor has conducted several hundred hours of analysis (e.g., computational analysis) and experimental testing (e.g., rotational load testing in a test rig) to arrive at the roller sub-assembly 17 disclosed herein. While, there is an almost infinite number of combinations of

materials that could be used for the roller 22, the pin 24, the rolling elements 28 and the housing 18, the inventor has identified several novel and non-obvious combinations of materials that achieve the extending life criteria disclosed above. For example, in one non-limiting embodiment, the pin 24 is manufactured from M50 VIM-VAR (i.e., Vacuum Induction Melt and Vacuum Arc Remelted) per AMS 6491 with a nitriding surface treatment; the roller 22 is manufactured from SAE 52100 per AMS 6440; the rolling elements 28 are manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening. The housing 18 is manufactured from a hardenable material. In one embodiment and as shown in FIG. 3, a hardened thrust washer 80 is positioned between the inwardly facing wall 20B of the prong 18B and the first end face 29B of the roller 22; and another hardened thrust washer 80 is positioned between the inwardly facing wall 20C of the prong 18C and the second end face 29C of the roller 22. One of the washers 80 is secured to each of the inwardly facing wall 20B and the inwardly facing wall 20C, thereby preventing rotation of the washer 80 in relation to the inwardly facing wall 20B and the inwardly facing wall 20C and eliminating the need to have a hardened surface on the inwardly facing wall 20B and the inwardly facing wall 20C.

In one embodiment, the pin 24 is manufactured from M50 VIM-VAR (i.e., Vacuum Induction Melt and Vacuum Arc Remelted) per AMS 6491 with a nitriding surface treatment. While the pin 24 is described as being manufactured from M50 VIM-VAR per AMS 6491 with a nitriding surface treatment, the present invention is not limited in this regard as the pin 24 may be manufactured from other suitable materials, including but not limited to: a) standard SAE 52100 material (AMS 6440); b) AMS 6440, AMS 6444 52100 Vacuum Arc Remelted (VAR); c) AMS 6444 VAR 52100 made with a Vacuum Induction Melt (VIM) step; or d) 8620. In one embodiment, the pin 24 is manufactured using other processing including, but not limited to carburizing the 8620, carbonitriding, nitriding, or solution nitriding.

In one embodiment, the roller 22 is manufactured from SAE 52100 per AMS 6440. While the roller 24 is described as being manufactured from SAE 52100 per AMS 6440, the present invention is not limited in this regard as the roller 22 may be manufactured from other suitable materials, including but not limited to: a) AMS 6440, AMS 6444 52100 Vacuum Arc Remelted (VAR); b) AMS 6444 VAR 52100 adding a Vacuum Induction Melt (VIM) step; c) 8620; or d) M50. In one embodiment, the roller 22 is manufactured using other processing including, but not limited to carburizing the 8620, carbonitriding, nitriding, or solution nitriding.

In one embodiment, the rolling elements 28 are manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening. While the rolling elements 28 are described as being manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening, the present invention is not limited in this regard as the rolling elements may be manufactured from
5 other suitable materials, including but not limited to: a) AMS 6440, AMS 6444 52100 Vacuum Arc Remelted (VAR); b) AMS 6444 VAR 52100 adding a Vacuum Induction Melt (VIM) step; or c) M50. In one embodiment, the roller 22 is manufactured using other processing including, but not limited to carburizing the 8620, carbonitriding, nitriding, or solution nitriding.

In one embodiment, the housing 18 is manufactured from a hardenable iron or steel for, example, but not limited to SAE 52100 steel and is through hardened, for example, by induction
10 hardening. In one embodiment, the housing 18 is manufactured from a case hardenable steel, for example, but not limited to SAE 8620H steel and is surface hardened, for example, but not limited to carburizing or hardening. In one embodiment, the housing 18 is manufactured from a case hardenable steel, for example, but not limited to SAE 8620H steel and is surface hardened.
15 For example, in this embodiment, the housing is carburized and hardened to reach a minimum hardness of Rockwell C 50. In one embodiment, the hardening of the housing 18 is accomplished by direct quench, induction, laser or other means. In one embodiment, only the inwardly facing wall 20B of the prong 18B and the inwardly facing wall 20C of the prong 18C are induction hardened. In one embodiment, only the inwardly facing wall 20B of the prong 18B
20 and the inwardly facing wall 20C of the prong 18C are surface hardened with the laser treatment. While the housing 18 and/or the inwardly facing wall 20B and the inwardly facing wall 20C are described as being manufactured from SAE 52100 steel or SAE 8620H steel and induction hardened or surface hardened, the present invention is not limited in this regard as the housing 18 and the inwardly facing wall 20B and the inwardly facing wall 20C may be manufactured from
25 other materials and/or treated by other processes including but not limited to through hardening to at least Rockwell C 50 via induction hardening methods and surface hardening via laser hardening or carburizing techniques.

While the present disclosure has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made
30 and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or

material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A roller assembly for a diesel engine used in a high mileage vehicle, the roller assembly comprising:
 - 5 a roller having an exterior roller surface and an interior surface that defines a bore extending therethrough;
 - a pin positioned in the bore and defining an exterior pin surface; and
 - a plurality of rolling elements positioned between the exterior pin surface and the interior surface of the roller, each of the plurality of rolling elements rollingly engages the exterior pin
 - 10 surface and the interior surface of the roller;
 - the roller assembly defines a clearance of between about 0.01 mm to about 0.03 mm between the rolling elements, the exterior pin surface and the interior surface; and
 - the roller assembly is configured to achieve extended life criteria for the diesel engines used in the high mileage vehicles, the extended life criteria comprises the clearance not
 - 15 increasing to more than 0.02 mm to 0.06 mm after 500,000 miles of travel of a vehicle powered by a diesel engine having the roller assembly installed therein.
2. The roller assembly of claim 1, wherein:
 - the pin is manufactured from one of M50 VIM-VAR per AMS 6491 with a nitriding surface treatment, SAE 52100 per AMS 6440 with a carbonitriding surface hardening, or SAE
 - 5 52100 per AMS 6440 induction hardened with a carbonitriding surface hardening.
3. The roller assembly of claim 1, wherein:
 - the roller is manufactured from SAE 52100 per AMS 6440.
4. The roller assembly of claim 1, wherein:
 - the rolling elements are manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening.

5. The roller assembly of claim 1, wherein:
the pin is manufactured from one of M50 VIM-VAR per AMS 6491 with a nitriding surface treatment, SAE 52100 per AMS 6440 with a carbonitriding surface hardening, or SAE 52100 per AMS 6440 induction hardened with a carbonitriding surface hardening;
- 5 the roller is manufactured from SAE 52100 per AMS 6440; and
the rolling elements are manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening.
6. The roller assembly of claim 1, wherein;
each of the rolling elements have a first diameter;
the roller defines a roller inner diameter and a roller outer diameter and a defines a radial
- 5 thickness equal to about one half of the roller outside diameter minus about one half of the roller inside diameter; and
wherein the radial thickness is between about one to two times the first diameter.

7. A cam and follower assembly for a diesel engine used in a high mileage commercial vehicle, the cam and follower assembly comprising:

a cam mounted on a cam shaft, the cam defining an exterior cam surface;

5 a follower assembly including a housing having a roller assembly rotatably mounted therein;

the roller assembly comprising,

a roller having an exterior roller surface and an interior surface that defines a bore extending therethrough, the exterior roller surface engaging the exterior cam surface,

a pin positioned in the bore and defining an exterior pin surface, and

10 a plurality of rolling elements positioned between the exterior pin surface and the interior surface of the roller, each of the plurality of rolling elements rollingly engages the exterior pin surface and the interior surface of the roller,

the roller assembly defines a clearance of between about 0.01 mm to about 0.03 mm between the rolling elements, the exterior pin surface and the interior surface, and

15 the roller assembly is configured to achieve extended life criteria for the diesel engines used in the high mileage vehicles, the extended life criteria comprises the clearance not increasing to more than 0.02 mm to 0.06 mm after 500,000 miles of travel of a vehicle powered by a diesel engine having the roller assembly installed therein; and wherein the follower assembly is configured to achieve extended life criteria for diesel
20 engines used in higher mileage vehicles.

8. The cam and follower assembly of claim 7, wherein:

the housing is manufactured from a hardenable steel and is surface hardened to at least Rockwell C 50.

5

9. The cam and follower assembly of claim 8, wherein a portion of the housing is surface hardened.

10. The cam and follower assembly of claim 7, wherein:
the pin is manufactured from M50 VIM-VAR per AMS 6491 with a nitriding surface treatment.
11. The cam and follower assembly of claim 7, wherein:
the roller is manufactured from SAE 52100 per AMS 6440.
12. The cam and follower assembly of claim 7, wherein:
the rolling elements are manufacture
d from SAE 52100 per AMS 6440 with carbonitriding surface hardening.
13. The cam and follower assembly of claim 7, wherein:
the pin is manufactured from M50 VIM-VAR per AMS 6491 with a nitriding surface treatment;
5 the roller is manufactured from SAE 52100 per AMS 6440;
the rolling elements are manufactured from SAE 52100 per AMS 6440 with carbonitriding surface hardening; and
the housing is manufactured from material hardenable to at least Rockwell C 50.
14. The cam and follower assembly of claim 13, wherein a portion of the housing is surface hardened.
15. The cam and follower assembly of claim 7, wherein:
a thrust washer is disposed between the roller and the housing.

FIG. 1

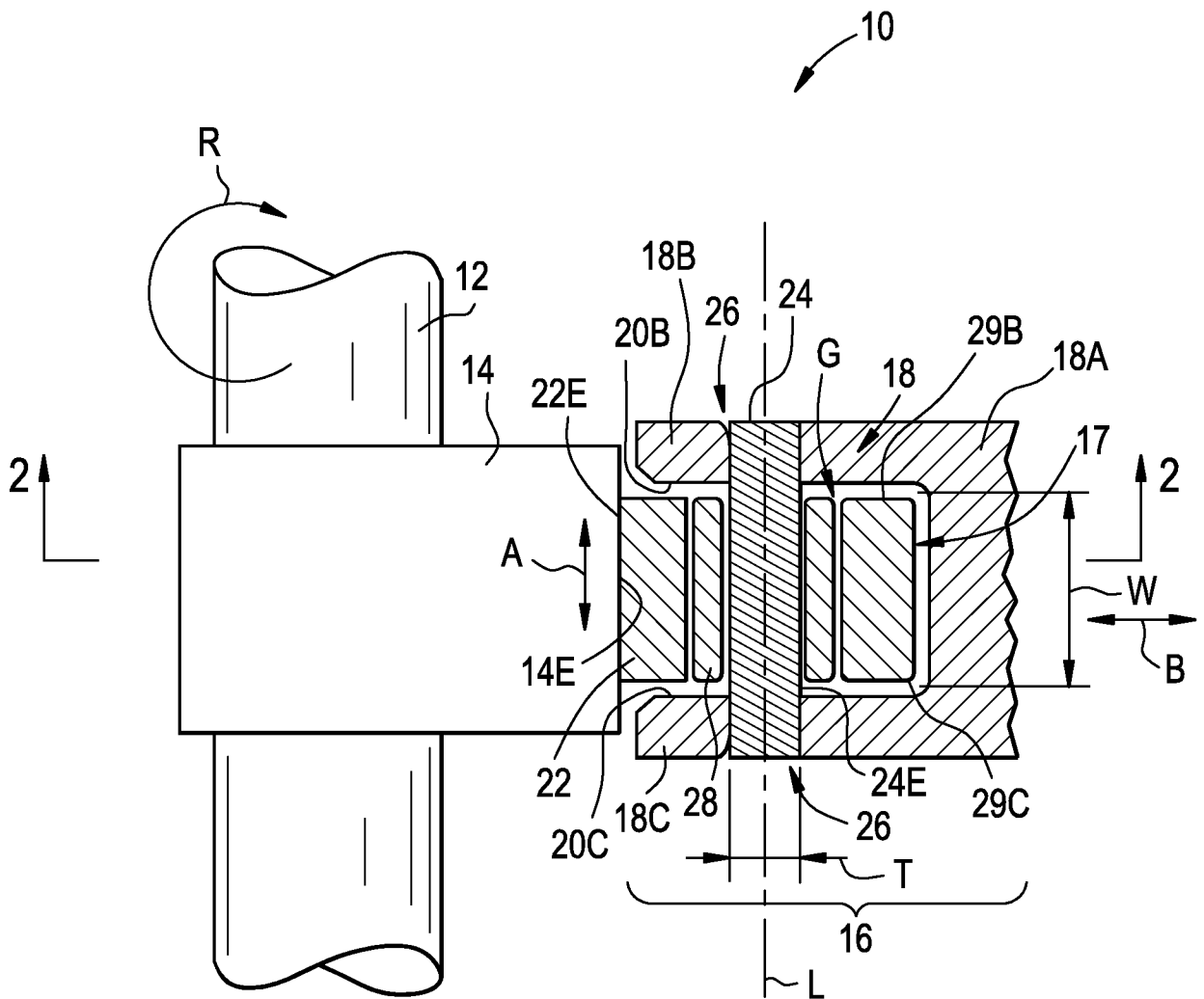


FIG. 2

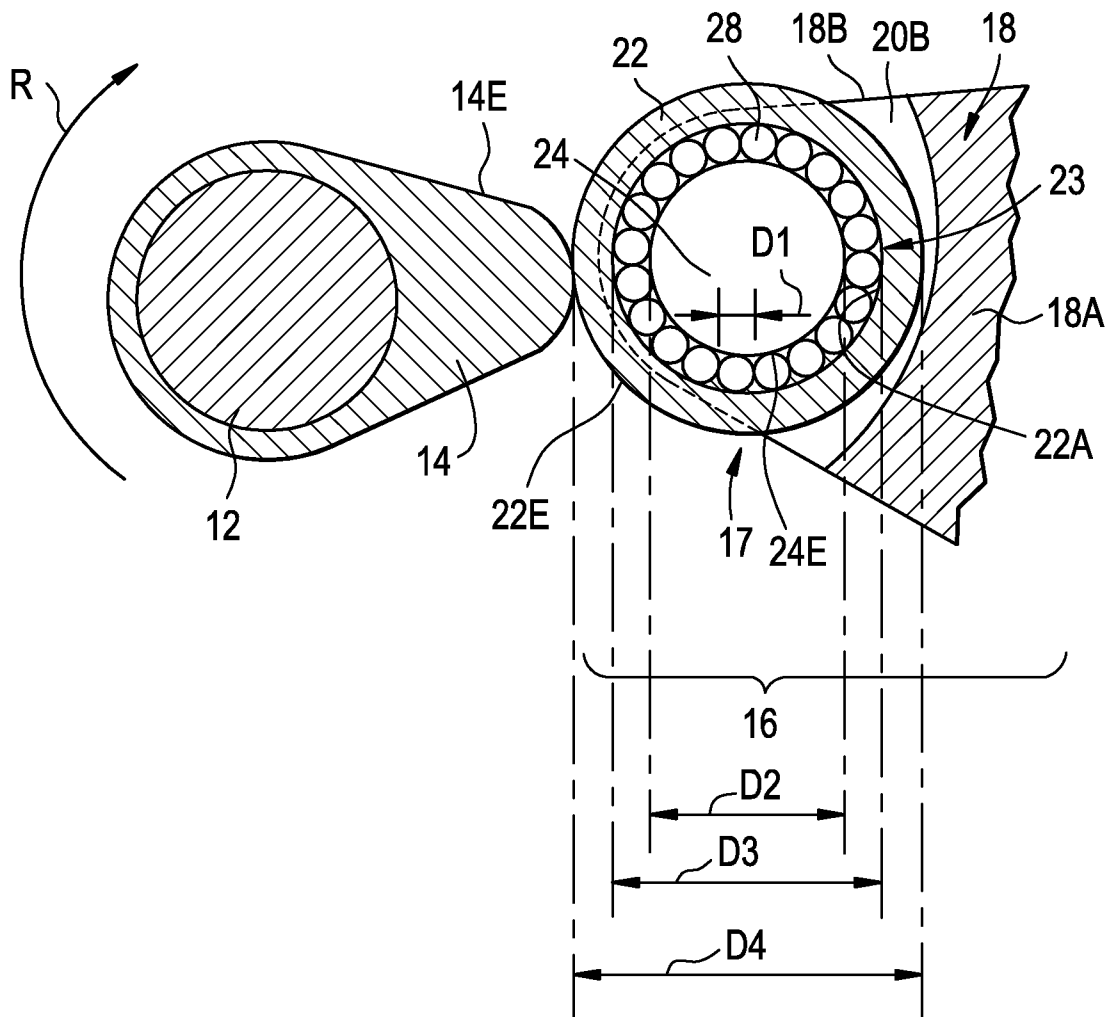


FIG. 3

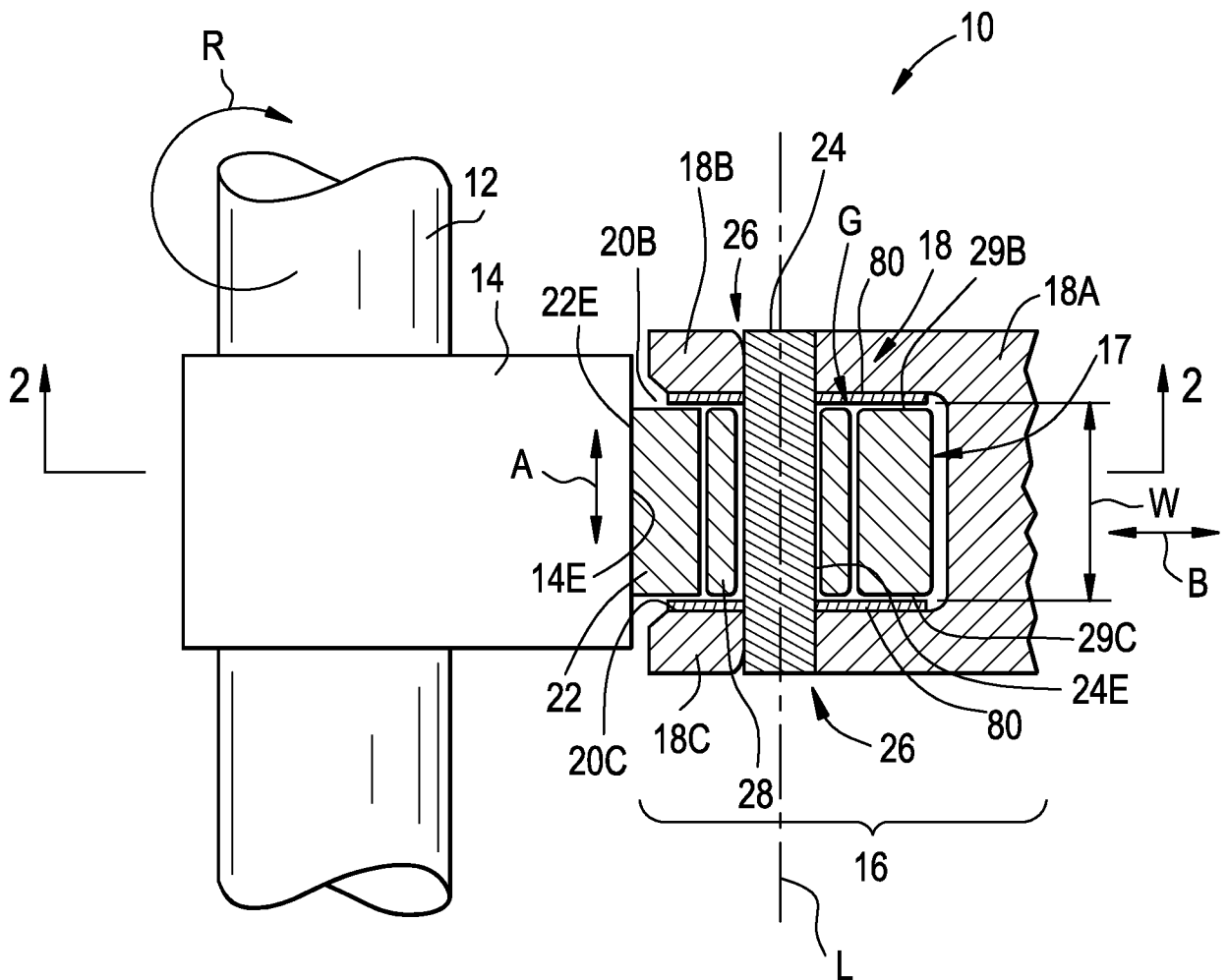
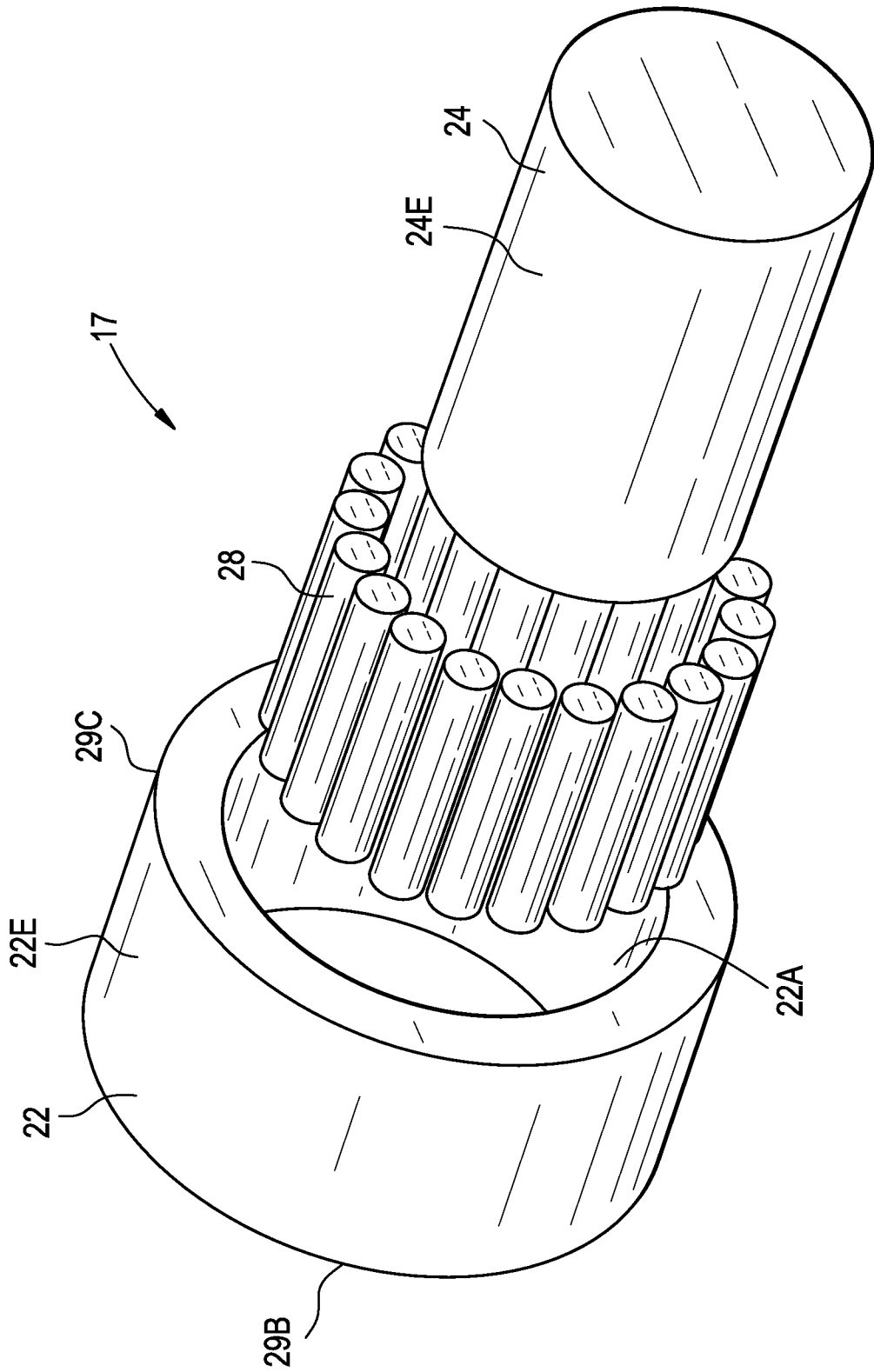


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/027954

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01L1/12 F01L1/18
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
F01L F16C
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/116269 A1 (NTN TOYO BEARING CO LTD [JP]; NAKAJIMA TATSUO [JP]; NAKAMURA YUICHIRO) 24 September 2009 (2009-09-24)	1,7
Y	the whole document	2-4,6,8-12,15
A		5,13,14
X	US 2002/000214 A1 (HARIMOTO KAZUYOSHI [JP] ET AL) 3 January 2002 (2002-01-03)	1,7
Y	the whole document	2-4,6,8-12,15
X	JP 2002 188643 A (NSK LTD) 5 July 2002 (2002-07-05)	1,7
Y	paragraphs [0019], [0020], [0039]; figure 1	6
	----- -/--	

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 25 August 2014	Date of mailing of the international search report 01/09/2014
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Clot, Pierre

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/027954

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"ENGINEERING FOR AIRFRAME CONTROL NEEDLE ROLLER BEARINGS", 1 January 2008 (2008-01-01), XP055132524, Retrieved from the Internet: URL: http://www.rbcbearings.com/aero-pdfs/Rolling/064_088/Ndl_AFC_Engin.pdf [retrieved on 2014-07-31] the whole document	2-4,8-12
Y	----- EP 1 788 264 A1 (NTN TOYO BEARING CO LTD [JP]) 23 May 2007 (2007-05-23) paragraph [0123]; figures 1,2	6
Y	----- US 4 727 832 A (MIYAMURA NORIYUKI [JP] ET AL) 1 March 1988 (1988-03-01)	8,9
A	claims 3-6; figure 3	14
Y	----- US 5 960 758 A (GIANNONE GUY ERNEST [US] ET AL) 5 October 1999 (1999-10-05) figures 2,3	15
Y	----- US 6 289 765 B1 (CLAYSON III RALPH LYLE [US]) 18 September 2001 (2001-09-18) column 3, lines 13-20; figures 2,3	15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2014/027954

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2009116269	A1	24-09-2009	NONE

US 2002000214	A1	03-01-2002	DE 10120527 A1 21-03-2002
			JP 2001303911 A 31-10-2001
			US 2002000214 A1 03-01-2002

JP 2002188643	A	05-07-2002	NONE

EP 1788264	A1	23-05-2007	EP 1788264 A1 23-05-2007
			EP 2159437 A2 03-03-2010
			EP 2345822 A2 20-07-2011
			US 2008163839 A1 10-07-2008
			WO 2006013696 A1 09-02-2006

US 4727832	A	01-03-1988	NONE

US 5960758	A	05-10-1999	BR 9901447 A 18-04-2000
			EP 0955450 A2 10-11-1999
			US 5960758 A 05-10-1999

US 6289765	B1	18-09-2001	NONE
