



- (51) International Patent Classification:
F16B 1/00 (2006.01) *F16B 43/00* (2006.01)
- (21) International Application Number:
PCT/US2016/052805
- (22) International Filing Date:
21 September 2016 (21.09.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/221,403 21 September 2015 (21.09.2015) US
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(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, KW, KZ, LA, LC, LK, LR, LS, 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, ST, 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).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: POST INSTALLATION INSPECTABLE COUNTERSUNK WASHER AND METHOD OF USE

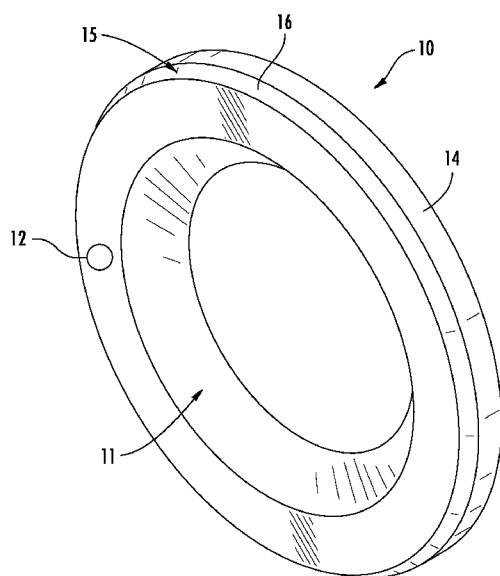


FIG. 1

(57) Abstract: Countersunk washers and methods of installation are provided in which a countersunk washer (10) has an inner diameter, an outer diameter, an upper surface (12), a lower surface (13), and an outer edge (14). The countersunk washer (10) comprises an inner diameter chamfer (11) sloping from the upper surface (12) towards the lower surface (13) and an indicator element (15) on a portion of the outer edge (14) at or near one of the upper surface (12) or the lower surface (13). In this configuration, the indicator element (15) is configured to distinguish the upper surface (12) from the lower surface (13) as viewed from the outer edge (14) before or after installation.

POST-INSTALLATION INSPECTABLE COUNTERSUNK WASHER AND METHOD OF USE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Patent Application Serial No. 62/221,403, filed September 21, 2015, the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF INVENTION

[0002] The subject matter disclosed herein generally relates to the design and inspectability of fasteners and in particular to countersunk washers installed under the head of a bolt with a fillet radii.

BACKGROUND

[0003] Many bolts have fillet radii under their bolt head for increased strength. This feature can prevent a straight washer from being positioned directly under the bolt head because of interference between the inner diameter of the straight washer and the under bolt head fillet. Accordingly, countersunk (CS) washers are often used in many products and industries, including the aviation industry, to provide the necessary clearance for fillet radii. Unfortunately, it is possible to install the countersunk washer upside-down such that the clearance is not aligned with the fillet radii. When this occurs, the improper installation can lead to washer and/or bolt damage. Either of which could lead to the concern for reduced fatigue life of the countersunk washer and bolt, and potentially premature failure under the bolt head. In most cases, once the countersunk washer and bolt are fully installed, the upside-down countersunk washer looks like it is correctly installed. This may be due to non-countersunk portion of the washer being forced on the shaft of the bolt and up and around the fillet radii, the washer concaving upward, and/or the introduction of a material failure of the countersunk washer. In any situation, it is exceedingly difficult to inspect this assembly with normal hardware, and it is almost impossible when working in tight or hard to view locations.

[0004] One custom fix to this issue is a double-countersunk washer so it is fully symmetric and cannot be incorrectly installed. Unfortunately, to meet load requirements, such double-

countersunk washers generally require an increase of thickness (e.g., two to three times or more), which adds substantial weight and creates the need for increased space. Also, a double-countersunk washer thickness correspondingly requires the use of longer bolts, all of which consumed more space and adds weight and cost. Such a result is particularly problematic in the aviation industry, where weight and space are two concerns that are critical elements of any fixed wing aircraft or helicopter design. Furthermore, the double-countersunk washer changes the load path of the bolt, which increases stress on the part below the bolt and countersunk-washer.

[0005] As a result, there exists a need for a countersunk washer that can easily minimize incorrect installation while also being easily inspected or verified after installation for correct installation. Finally it would be desirable for such a washer to not add thickness or weight to the countersunk washer or the bolt it is being installed with, all while maintaining the designed load path and avoiding changed paths for stress in the part below the bolt head.

SUMMARY

[0006] In one aspect, a countersunk washer is provided. The countersunk washer has an inner diameter, an outer diameter, an upper surface, a lower surface, and an outer edge. The countersunk washer comprises an inner diameter chamfer sloping from the upper surface towards the lower surface and an indicator element on a portion of the outer edge at or near one of the upper surface or the lower surface. In this configuration, the indicator element is configured to distinguish the upper surface from the lower surface as viewed from the outer edge.

[0007] In another aspect, a countersunk washer having an inner diameter, an outer diameter, an upper surface, a lower surface, and an outer edge is provided. The countersunk washer includes an inner diameter chamfer sloping from the upper surface towards the lower surface and an outer diameter chamfer sloping from the upper surface towards the lower surface and intersecting the outer edge. At least a portion of the outer diameter chamfer comprises a visual surface modification. In this configuration, the outer diameter chamfer is configured to distinguish the upper surface from the lower surface as viewed from the outer edge.

[0008] In another aspect, a method of installing a countersunk washer is provided. The method includes the steps of providing a bolt having a bolt head connected to a shaft portion, wherein a fillet radii is provided at the connection between the bolt head and the shaft portion,

and providing a countersunk washer, the countersunk washer including an inner diameter and an outer diameter, an upper surface, a lower surface, an outer edge, an inner diameter chamfer, the inner diameter chamfer sloping from the upper surface towards the lower surface, and an indicator element on the outer edge at or near one of the upper surface or the lower surface. The counter sunk washer is installed on the shaft portion such that the inner diameter chamfer is positioned proximate the fillet radii and the upper surface of the countersunk washer is flush with an underside of the bolt head. The countersunk washer is inspected to identify whether the indicator element is in an orientation corresponding with the inner diameter chamfer being positioned proximate the fillet radii. The bolt is then tightened to a desired tightness.

[0009] Although some of the aspects of the subject matter disclosed herein have been stated hereinabove, and which are achieved in whole or in part by the presently disclosed subject matter, other aspects will become evident as the description proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a perspective view of a countersunk washer according to an embodiment of the presently disclosed subject matter.

[0011] FIG. 2 is a plan view of the countersunk washer according to the embodiment of the presently disclosed subject matter shown in FIG. 1.

[0012] FIG. 3 is a side view of the countersunk washer according to the embodiment of the presently disclosed subject matter shown in FIG. 1.

[0013] FIG. 4A is an exploded view of a countersunk washer on the shaft of a bolt immediately below the fillet radii according to an embodiment of the presently disclosed subject matter.

[0014] FIG. 4B is a section view of the countersunk washer on the shaft of the bolt immediately below the fillet radii according to the embodiment of the presently disclosed subject matter shown in FIG. 4A.

[0015] FIG. 4C is a detail view of the countersunk washer on the shaft of the bolt immediately below the fillet radii according to the embodiment of the presently disclosed subject matter shown in FIG. 4B.

[0016] FIG. 4D is a perspective view of a countersunk washer the shaft of a bolt immediately below the fillet radii according to an embodiment of the presently disclosed subject matter.

[0017] FIG. 5A is a side view of a countersunk washer installed with a bolt and the outer diameter chamfer facing toward the underside of the bolt head according to an embodiment of the presently disclosed subject matter.

[0018] FIG. 5B is a section view of the countersunk washer installed with bolt and the outer diameter chamfer facing toward the underside of the bolt head according to the embodiment of the presently disclosed subject matter shown in FIG. 5A.

[0019] FIG. 5C is a detail view of the countersunk washer installed with bolt and the outer diameter chamfer facing toward the underside of the bolt head according to the embodiment of the presently disclosed subject matter shown in FIG. 5B.

[0020] FIG. 5D is a perspective view of a countersunk washer installed with a bolt and the outer diameter chamfer facing toward the underside of the bolt head according to an embodiment of the presently disclosed subject matter.

[0021] FIGS. 6 and 7 are side views of countersunk washers according to embodiments of the presently disclosed subject matter.

[0022] FIG. 8 is a perspective view of a countersunk washer installed with a bolt against a mated part in a correct orientation such that an indicator element is visible according to an embodiment of the presently disclosed subject matter.

[0023] FIG. 9 is a perspective view of a countersunk washer installed with a bolt against a mated part in an incorrect orientation such that an indicator element is obscured according to an embodiment of the presently disclosed subject matter.

DETAILED DESCRIPTION

[0024] The presently disclosed subject matter addresses the problems encountered with conventional countersunk washers by introducing improved countersunk washers and methods of installation that can easily minimize incorrect installation. The countersunk washers disclosed can be easily inspected and verified after installation, and they do not add thickness

or weight to the countersunk washer or the bolt with which it is being installed, all while maintaining the designed load path and avoid changing the path of stress to and in the part below the bolt head.

[0025] Referring now to FIGS. 1-9 a new countersunk washer, generally designated **10**, is provided. As illustrated, countersunk washer **10** defines an upper surface **12**, a lower surface **13** substantially opposing upper surface **12**, an outer edge **14**, and an inner diameter chamfer **11** (e.g., having a slope with an angle of between about 10 degrees and 80 degrees with respect to upper surface **12**). Countersunk washer **10** further includes an indicator element, generally designated **15**, on a portion of outer edge **14** at or near one of upper surface **12** or lower surface **13**. This indicator element **15** provides an external visual indicator of the orientation of countersunk washer **10**, even when in an as-installed position. In this way, a user is able to more readily identify whether countersunk washer **10** is installed in the intended configuration or if it is upside-down.

[0026] In the embodiment illustrated in FIGS. 1-5D, indicator element **15** comprises an outer diameter chamfer **16**. In some embodiments, outer diameter chamfer **16** has a 30/60 degree angle, although those having ordinary skill in the art will recognize that any of a range of chamfer angles (e.g., between about 20 and 70 degrees with respect to outer edge **14**) can be used as long as indicator element **15** is visible in the desired scenario as discussed below. Alternatively, in some embodiments, one or both of inner diameter chamfer **11** and/or outer diameter chamfer **16** is formed as radii rather than as chamfers. In some embodiments, outer diameter chamfer **16** is formed by machining, lathing, or otherwise mechanically modifying countersunk washer **10**. In some alternative embodiments, rather than a continuous chamfer about the outer diameter of countersunk washer **10**, indicator element **15** is provided as one or more notches, cutouts, or other surface features on one of upper surface **12** or lower surface **13** at or near outer edge **14**.

[0027] In any of these configurations, countersunk washer **10** uses less material than a standard washer while maintaining the necessary load carrying capability since the removal of material resulting from the formation of indicator element **15** does not substantially affect the load area for countersunk washer **10** and an associated fastener. Rather, this weight reduction maintains the design load transfer from the fastener and does not introduce stress path changes to the fastener, countersunk washer **10**, and the associated part to which the fastener is coupled.

[0028] Alternatively or in addition, in some embodiments, indicator element **15** comprises a visual surface modification configured to distinguish upper surface **12** from lower surface **13** as viewed from outer edge **14** before or after installation. In some embodiments, such a visual surface modification includes a surface texture on one or more of a portion of outer edge **14**, upper surface **12**, and/or lower surface **13** to increase the visibility of indicator element **15**. In some embodiments, such a surface texture is applied by other machining steps such as knurling, dot peening, etching, or another form of surface texturing. In some embodiments, such as that illustrated in FIG. 6, indicator element **15** includes outer diameter chamfer **16** that is knurled to improve its visibility and thus provide enhanced contrast between a first portion of outer edge **14** that is proximate upper surface **12** and a second portion of outer edge **14** that is proximate lower surface **13**. Alternatively, in some embodiments, such as that illustrated in FIG. 7, indicator element **15** is a textured edge portion **17** that does not have a chamfer. In any configuration, in some embodiments, one benefit of indicator element **15** including a textured surface feature (e.g., knurling, dot peening, etching, notches, cutouts) is the ability to provide a tactile distinction between a first portion of the outer edge proximate the upper surface and a second portion of the outer edge proximate the lower surface. In such embodiments, a user is able to inspect by touch or gage/probe checking for non-smooth surface in the correct location. Such a physical inspection can be performed either instead of or in addition to a visual inspection.

[0029] In yet further alternative embodiments, indicator element **15** comprises a visual surface modification in the form of color instead of or in addition to surface texture. In such embodiments, a colored portion of one or more of inner diameter chamfer **11**, upper surface **12**, lower surface **13**, and/or outer diameter chamfer **16** (if present) is configured to distinguish upper surface **12** from lower surface **13** as viewed from outer edge **14**. In some embodiments, this coloration is accomplished through application of a brightly colored molybdenum disulfide lubricant (“moly lube”), by painting, by anodizing, by using dye or stain, or by any of a variety of other known method of changing the color of a metal surface. The use of moly lube is particularly advantageous in some embodiments to reduce the potential for scratch/galling damage to the fillet radii on an associated fastener. In other embodiments in which countersunk washer **10** is composed of a material other than a metal, the coloration is done with a material-appropriate coloration technique(s) known to those skilled in the art. In any form, the use of coloration serves to reduce the likelihood of an incorrect installation, either by itself or in combination with a mechanical modification to washer **10** (e.g., outer diameter chamfer **16**).

In some embodiments, the coloration used is a bright or sharply contrasting color that is easily visible during installation of countersunk washer **10**. In some embodiments, outer edge **14** is not colored or is a significantly different and contrasting color than that used for indicator element **15**. In such embodiments, the addition of the bright and/or sharply-contrasting colored portions provides for a visible detection of whether countersunk washer **10** is correctly installed. This visible indicator significantly reduces the opportunity for incorrect installation and greatly enhances the quality inspection conducted by the post assembly inspector.

[0030] Regardless of the particular form, in some embodiments, indicator element **15** is formed or positioned on the same side of countersunk washer **10** as inner diameter chamfer **11** (e.g., at or near upper surface **12**). In this arrangement, indicator element **15** is visible both when countersunk washer **10** is positioned to receive a fastener and after the fastener is installed. FIGS. 4A through 4D illustrate various views of a bolt **20** being aligned with countersunk washer **10**. In this configuration, bolt **20** has a fillet radii **21** at the connection between a bolt head **22** of bolt **20** and a shaft portion **23** of bolt **20**. When countersunk washer **10** is in the designed alignment with inner diameter chamfer **11** oriented facing fillet radii **21** (See, e.g., FIGS. 4B and 4C), an installer that is inserting bolt **20** in place will see indicator element **13** as bolt head **22** is moved towards upper surface **12** of countersunk washer **10**. (See, e.g., FIG. 4D) In this configuration, prior to tightening of bolt **20** to a desired tightness, if countersunk washer **10** is installed upside-down, indicator element **15** is not visible from the perspective looking at bolt head **22**, and the installer may quickly correct the orientation of countersunk washer **10**.

[0031] Furthermore, in some embodiments, once bolt **20** is engaged with countersunk washer **10** such that inner diameter chamfer **11** is proximate fillet radii **21** of bolt **20** and upper surface **12** is flush with the underside of bolt head **22**, indicator element **15** remains visible at the interface between countersunk washer **10** and bolt head **22**. (See, e.g., FIGS. 5A through 5D) In such an embodiment, the visibility of indicator element **15** serves as a sign that countersunk washer **10** is properly installed in an orientation in which inner diameter chamfer **11** provides the desired clearance such that countersunk washer **10** does not engage fillet radii **21**.

[0032] Referring to FIG. 8, countersunk washer **10** and bolt **20** are shown installed (e.g., upon tightening of bolt **20** to a desired tightness) in a correct orientation with respect to an associated mated part, generally designated **30**. As illustrated, indicator element **15** remains

visible at the interface between countersunk washer **10** and bolt head **22**. In FIG. 9, however, countersunk washer **10** and bolt **20** are shown installed in an incorrect orientation in which countersunk washer **10** is upside-down with respect to bolt head **22**, and this installation is not fully clamped down (e.g., because of interference between fillet radii **21** and bottom surface **13** of countersunk washer **10**), so bolt head **22** remains offset farther from mated part **30** than in the correct installation illustrated in FIG 8. In this arrangement, indicator element **15** is oriented towards mated part **30** rather than towards bolt head **22** and is thus at least partially obscured by the interface between upper surface **12** and mated part **30**. In this way, a person conducting a post-installation inspection is able to readily identify whether countersunk washer **10** is installed in the proper orientation by identifying whether or not indicator element **15** is visible at the interface between countersunk washer **10** and bolt head **22**.

[0033] Alternatively, in some embodiments, indicator element **15** is formed or positioned on the opposite side of countersunk washer **10** as inner diameter chamfer **11** (e.g., at or near lower surface **13**). In this arrangement, indicator element **15** is designed to face away from the underside of bolt head **22** and will thus be most visible if countersunk washer **10** is improperly positioned to receive a fastener. In such embodiments, indicator element **15** is not visible at the interface between countersunk washer **10** and bolt head **22** after the fastener is installed, and thus identification of indicator element **15** during post-installation inspection indicates improper installation. Those having skill in the art will recognize that it is a design choice as to whether indicator element **15** serves more as a warning of improper installation or as a sign of proper installation.

[0034] Other embodiments of the current invention will be apparent to those skilled in the art from a consideration of this specification or practice of the invention disclosed herein. Thus, the foregoing specification is considered merely exemplary of the current invention with the true scope thereof being defined by the following claims.

CLAIMS

What is claimed is:

1. A countersunk washer having an inner diameter, an outer diameter, an upper surface, a lower surface, and an outer edge, the countersunk washer comprising:
 - an inner diameter chamfer sloping from the upper surface towards the lower surface;
 - and
 - an indicator element on a portion of the outer edge at or near one of the upper surface or the lower surface;
 - wherein the indicator element is configured to distinguish the upper surface from the lower surface as viewed from the outer edge before or after installation.
2. The countersunk washer of claim 1, wherein the indicator element comprises an outer diameter chamfer sloping either from the upper surface towards the lower surface or from the lower surface towards the upper surface, the outer diameter chamfer intersecting the outer edge.
3. The countersunk washer of claim 2, wherein a slope of the outer diameter chamfer has an angle of between about 20 and 70 degrees with respect to the outer edge.
4. The countersunk washer of claim 1, wherein the indicator element comprises a surface texture on one or more of a portion of the outer edge, the upper surface, and the lower surface.
5. The countersunk washer of claim 4, wherein the surface texture comprises one of knurling, dot peening, or etching.
6. The countersunk washer of claim 4, wherein the surface texture is configured to provide a tactile distinction between a first portion of the outer edge proximate the upper surface and a second portion of the outer edge proximate the lower surface.
7. The countersunk washer of claim 1, wherein at least a portion of one or more of the indicator element, the upper surface, the lower surface, and the inner diameter chamfer has a first color;
 - wherein the outer edge has a second color; and
 - wherein the first color visually contrasts against the second color.
8. The countersunk washer of claim 7, wherein the portion having the first color comprises a portion of the one or more of the indicator element, the upper surface, and the inner diameter

chamfer that is colored by one of a colored molybdenum disulfide lubricant, paint, anodization, dye, or stain.

9. The countersunk washer of claim 1, wherein a slope of the inner diameter chamfer has an angle of between about 10 degrees and 80 degrees with respect to the upper surface.

10. A countersunk washer having an inner diameter, an outer diameter, an upper surface, a lower surface, and an outer edge, the countersunk washer comprising:

an inner diameter chamfer sloping from the upper surface towards the lower surface;
and

an outer diameter chamfer sloping from the upper surface towards the lower surface and intersecting the outer edge;

wherein at least a portion of the outer diameter chamfer comprises a visual surface modification; and

wherein the outer diameter chamfer is configured to distinguish the upper surface from the lower surface as viewed from the outer edge.

11. The countersunk washer of claim 10, wherein the portion of the outer diameter chamfer that comprises a visual surface modification is colored by one of a colored molybdenum disulfide lubricant, paint, anodization, dye, or stain.

12. The countersunk washer of claim 10, wherein the portion of the outer diameter chamfer that comprises a visual surface modification comprises one of knurling, dot peening, or etching.

13. A method of installing a countersunk washer, the method comprising:

providing a bolt having a bolt head connected to a shaft portion, wherein a fillet radii is provided at the connection between the bolt head and the shaft portion;

providing a countersunk washer, the countersunk washer including:

an inner diameter and an outer diameter;

an upper surface;

a lower surface;

an outer edge;

an inner diameter chamfer, the inner diameter chamfer sloping from the upper surface towards the lower surface; and

an indicator element on a portion of the outer edge at or near one of the upper surface or the lower surface;

installing the counter sunk washer on the shaft portion such that the inner diameter chamfer is positioned proximate the fillet radii, and the upper surface of the countersunk washer is flush with an underside of the bolt head;

inspecting the countersunk washer to identify whether the indicator element is in an orientation corresponding with the inner diameter chamfer being positioned proximate the fillet radii; and

tightening the bolt to a desired tightness.

14. The method of claim 13, wherein providing a countersunk washer including an indicator element comprises providing a countersunk washer with an outer diameter chamfer, the outer diameter chamfer sloping either from the upper surface towards the lower surface or from the lower surface towards the upper surface, the outer diameter chamfer intersecting the outer edge.

15. The method of claim 14, wherein providing a countersunk washer with an outer diameter chamfer comprises lathing or machining the countersunk washer.

16. The method of claim 13, wherein providing a countersunk washer including an indicator element comprises applying a surface texture to one or more of a portion of the outer edge, the upper surface, and the lower surface.

17. The method of claim 16, wherein applying a surface texture comprises knurling, dot peening, or etching the one or more of the portion of the outer edge, the upper surface, and the lower surface.

18. The method of claim 16, wherein inspecting the countersunk washer comprises touching the outer edge to identify whether the surface texture is in an orientation corresponding with the inner diameter chamfer being positioned proximate the fillet radii.

19. The method of claim 13, wherein providing a countersunk washer comprises colorizing at least a portion of one or more of the indicator element, the upper surface, the lower surface, and the inner diameter chamfer.

20. The method of claim 19, wherein colorizing at least a portion of one or more of the indicator element, the upper surface, the lower surface, and the inner diameter chamfer

comprises applying a brightly colored molybdenum disulfide lubricant, paint, anodization, dye, or stain.

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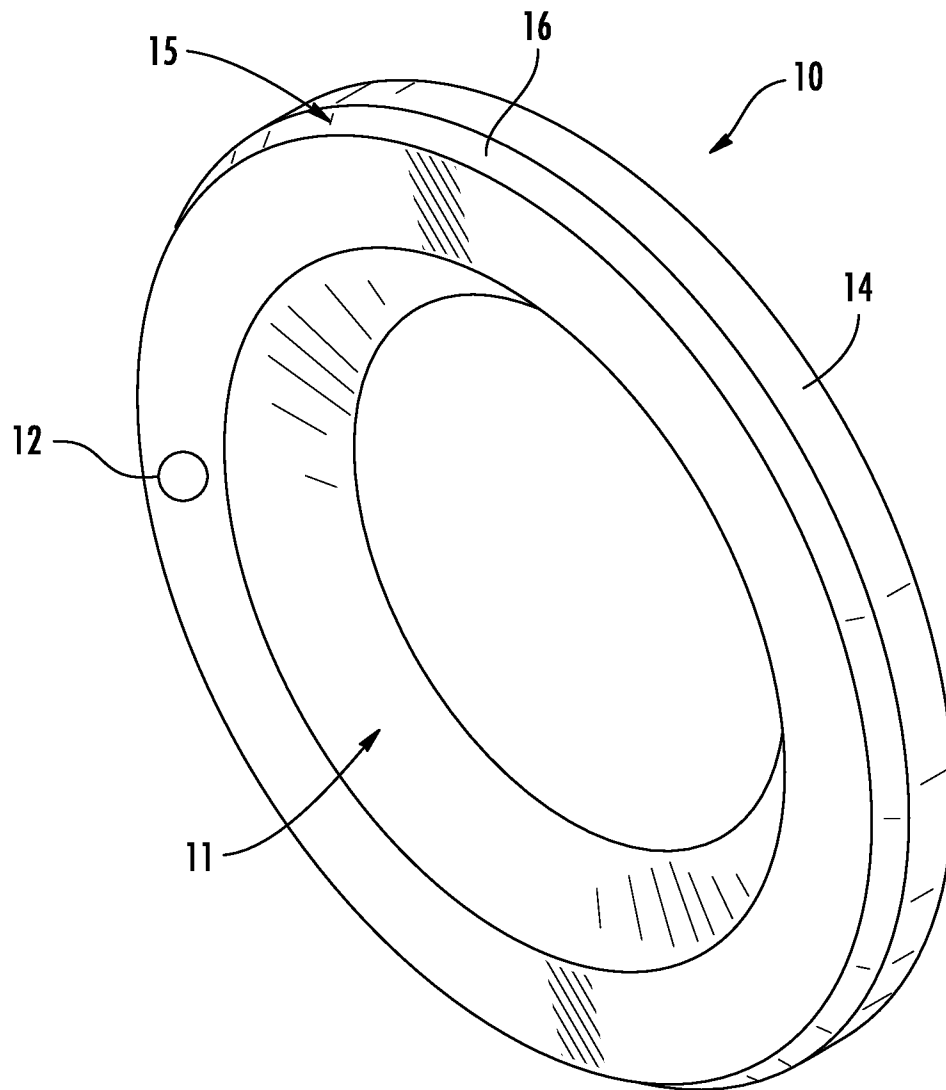


FIG. 1

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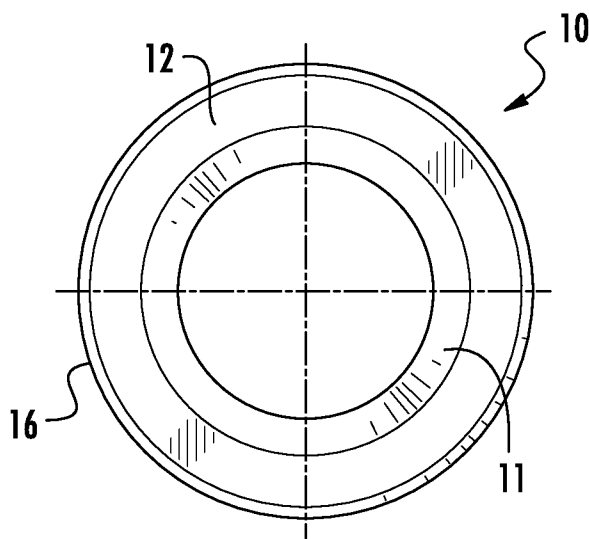


FIG. 2

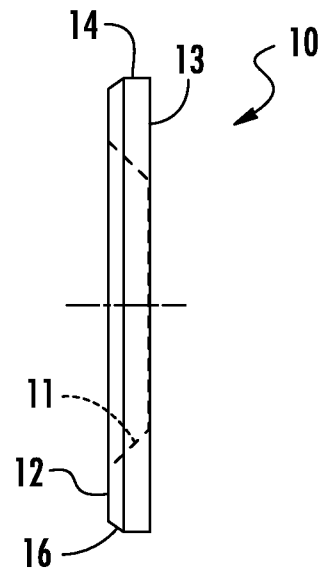


FIG. 3

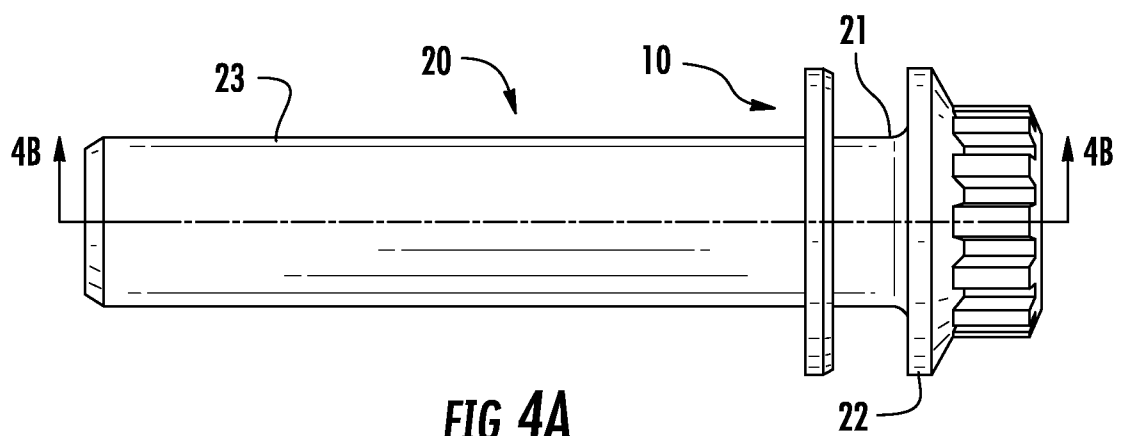


FIG. 4A

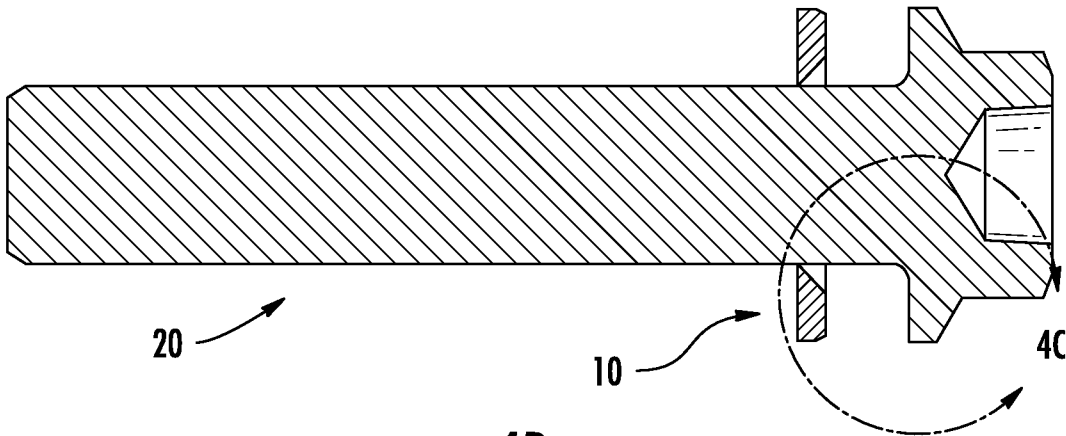


FIG. 4B

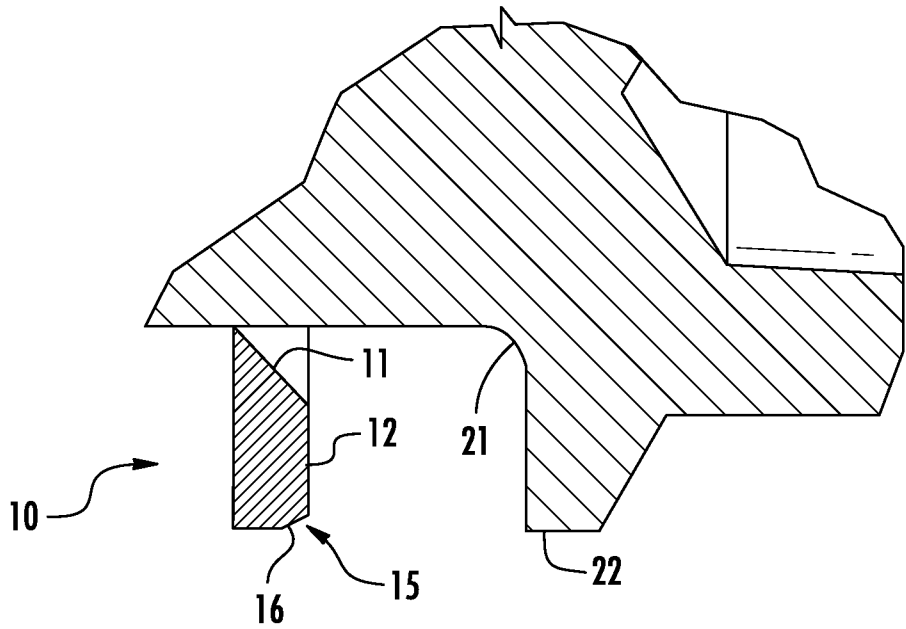
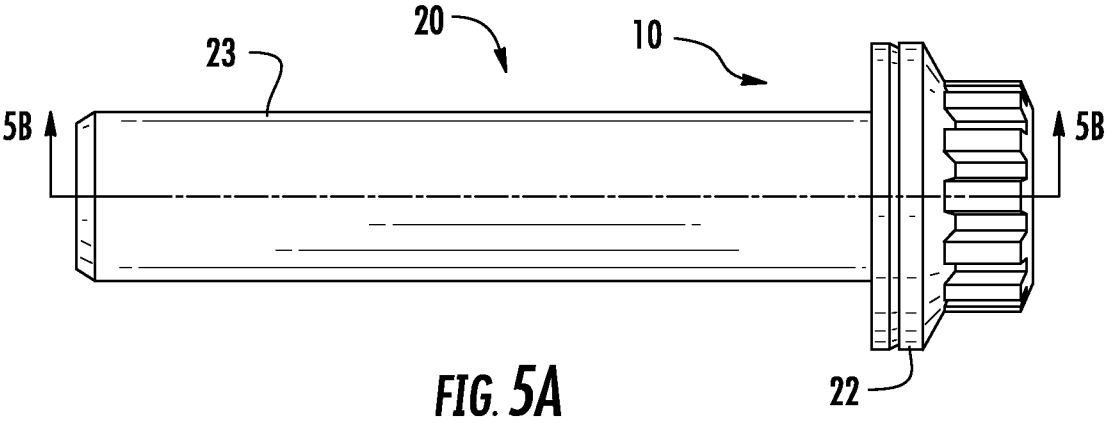
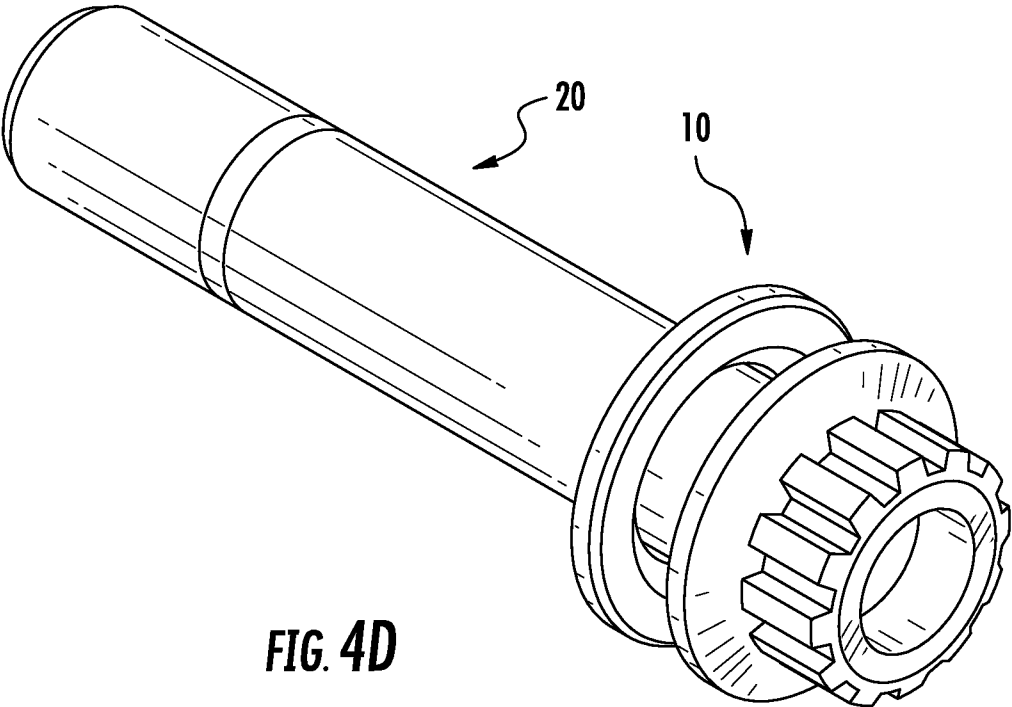


FIG. 4C



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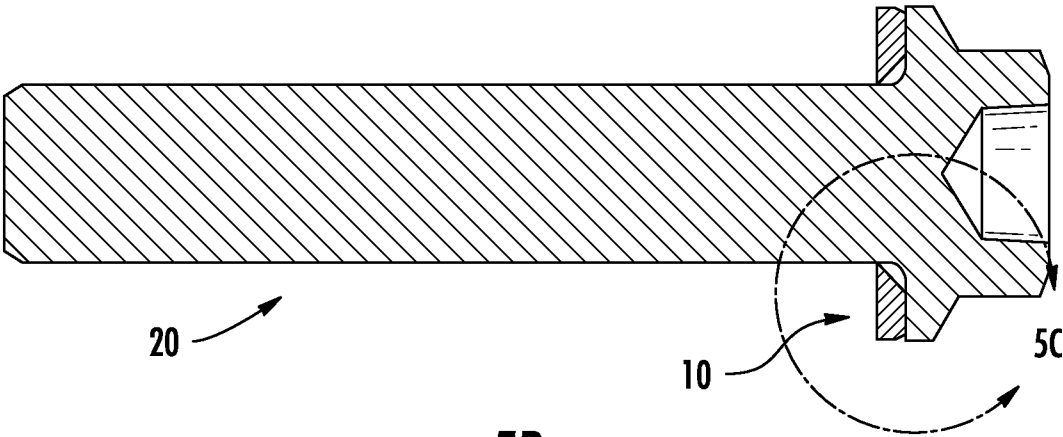


FIG. 5B

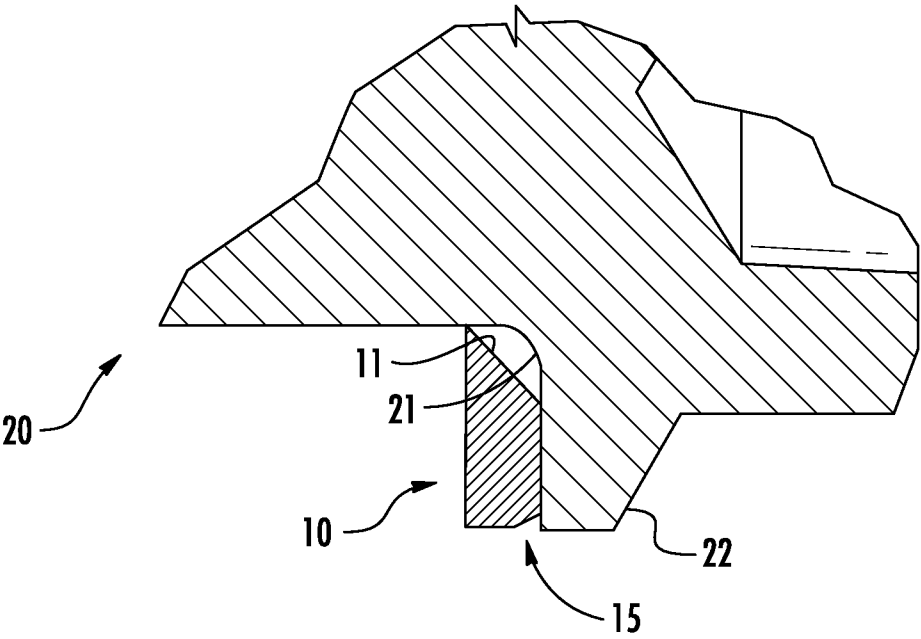


FIG. 5C

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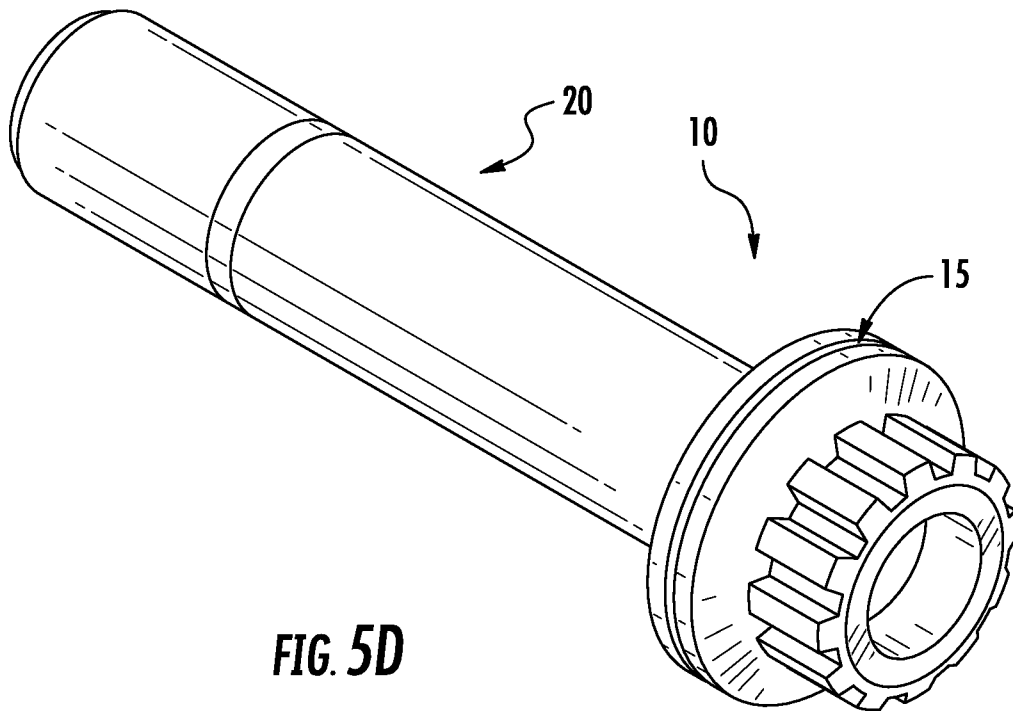


FIG. 5D

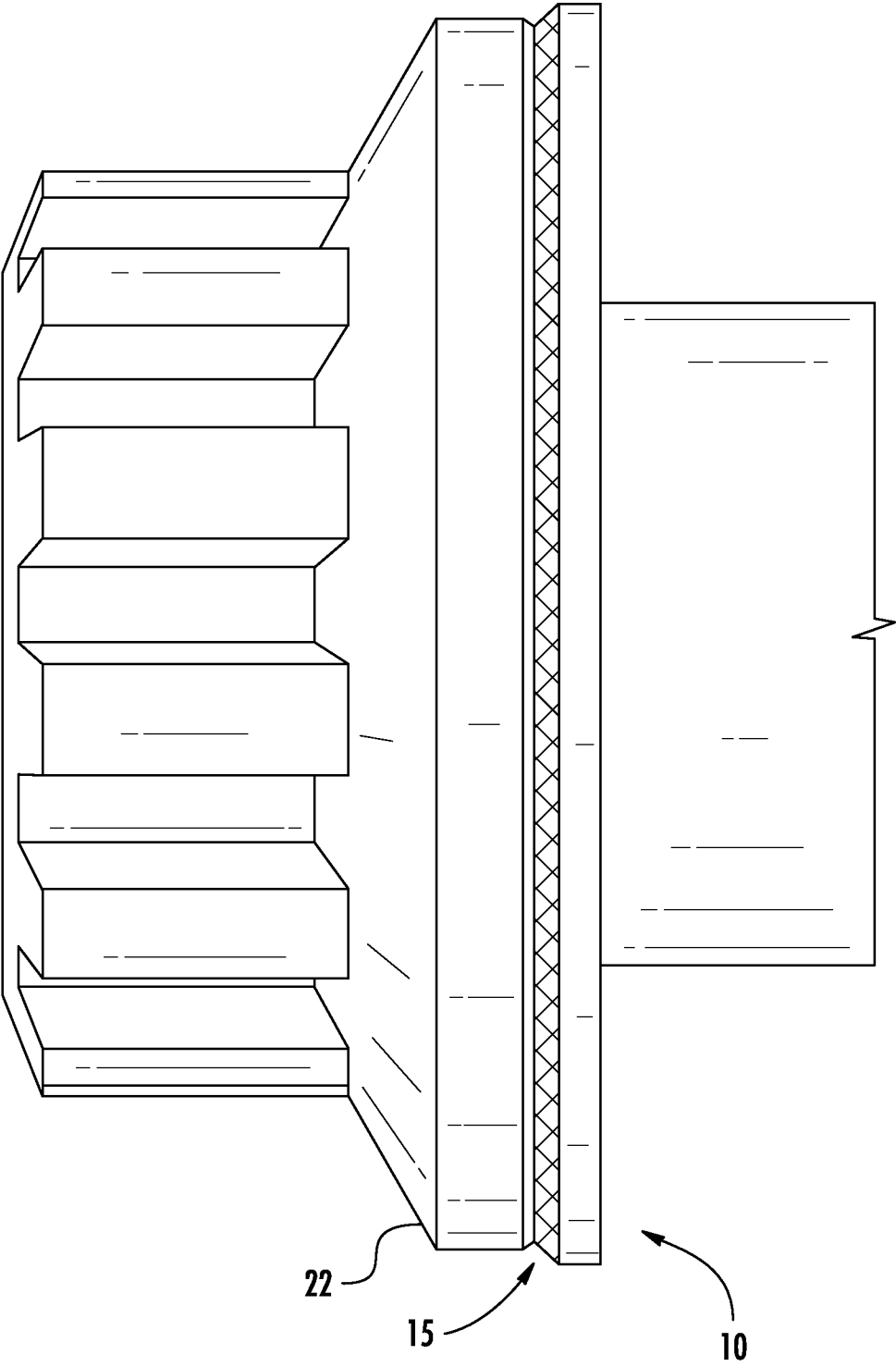


FIG. 6

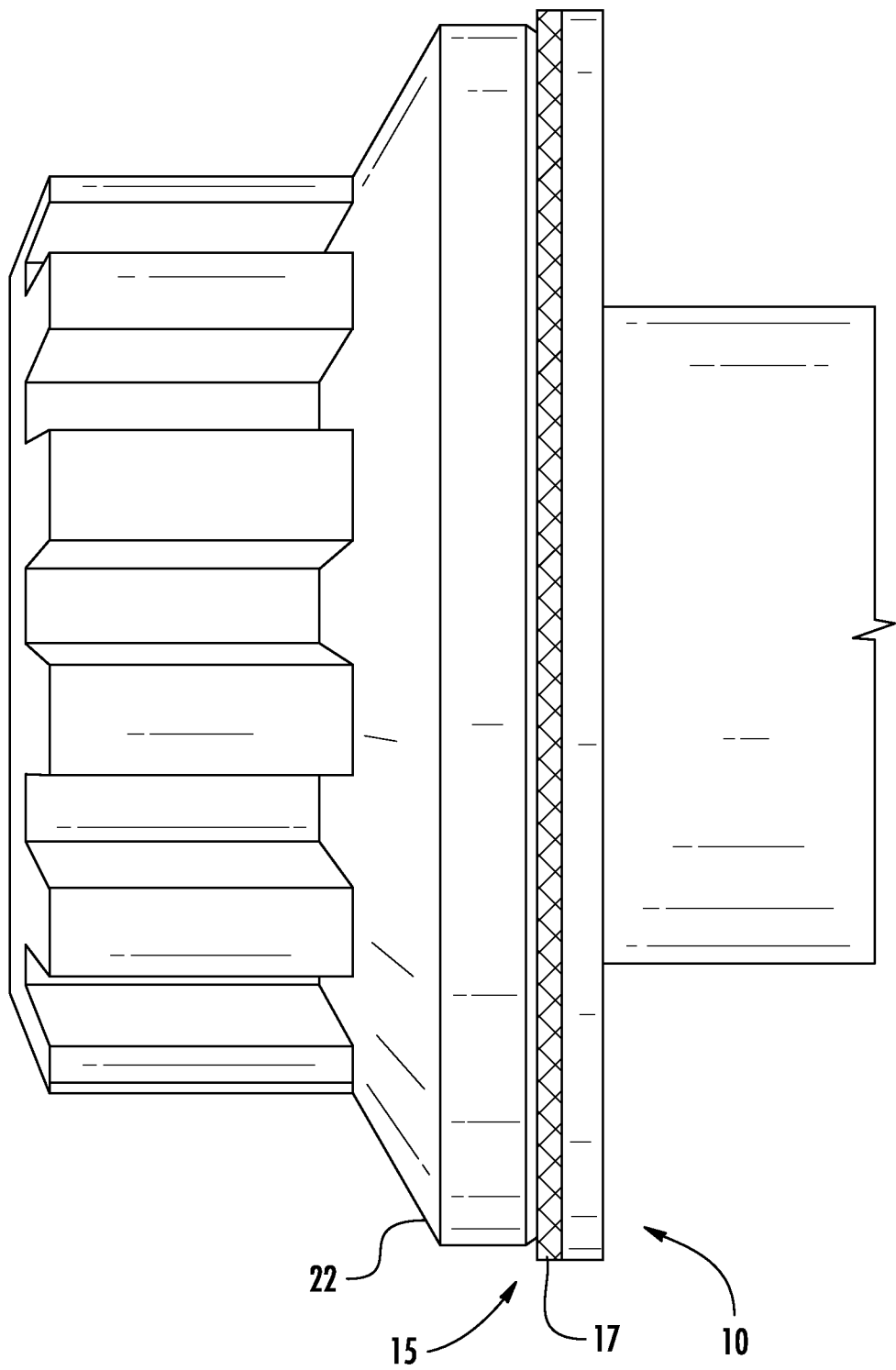


FIG. 7

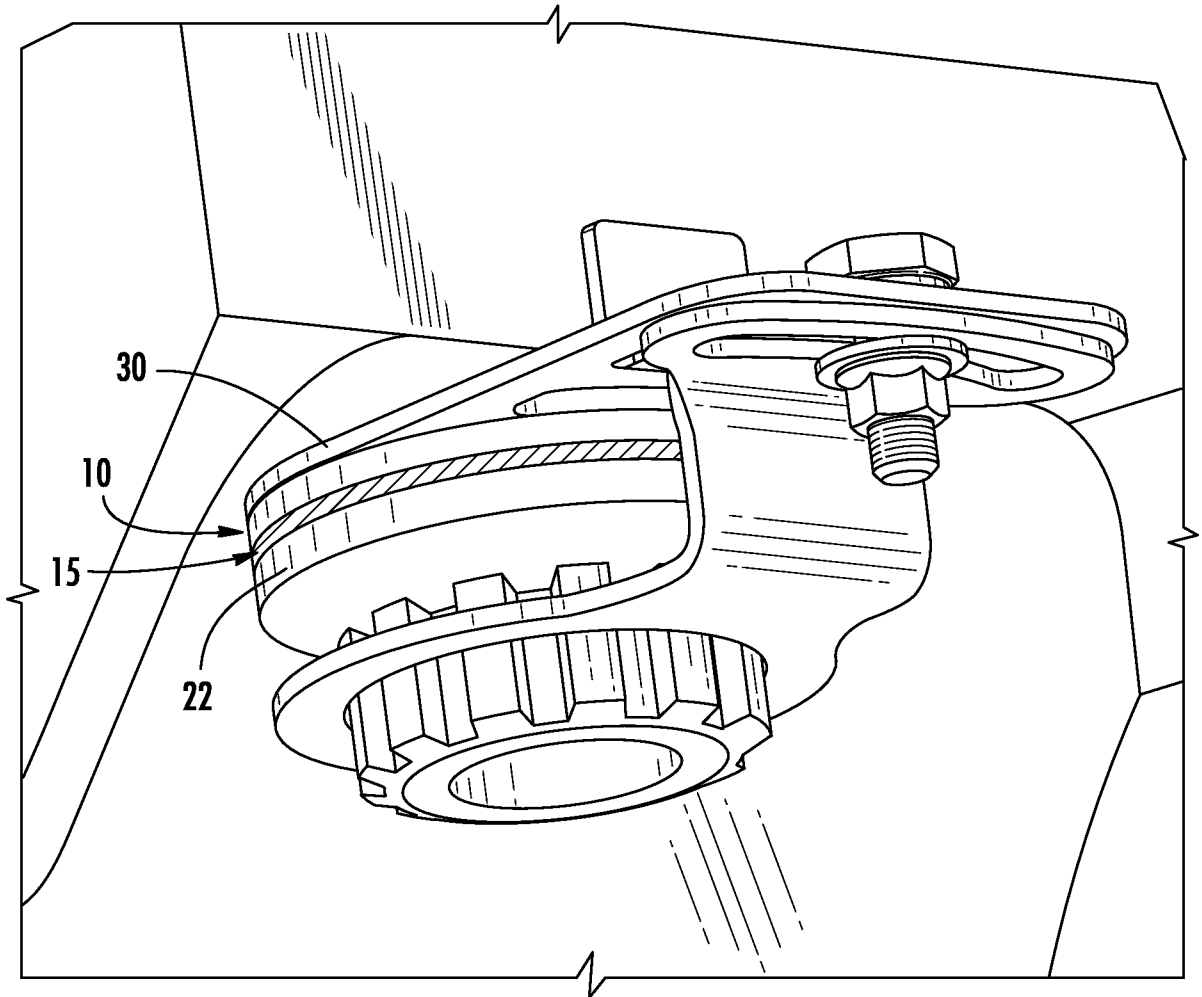


FIG. 8

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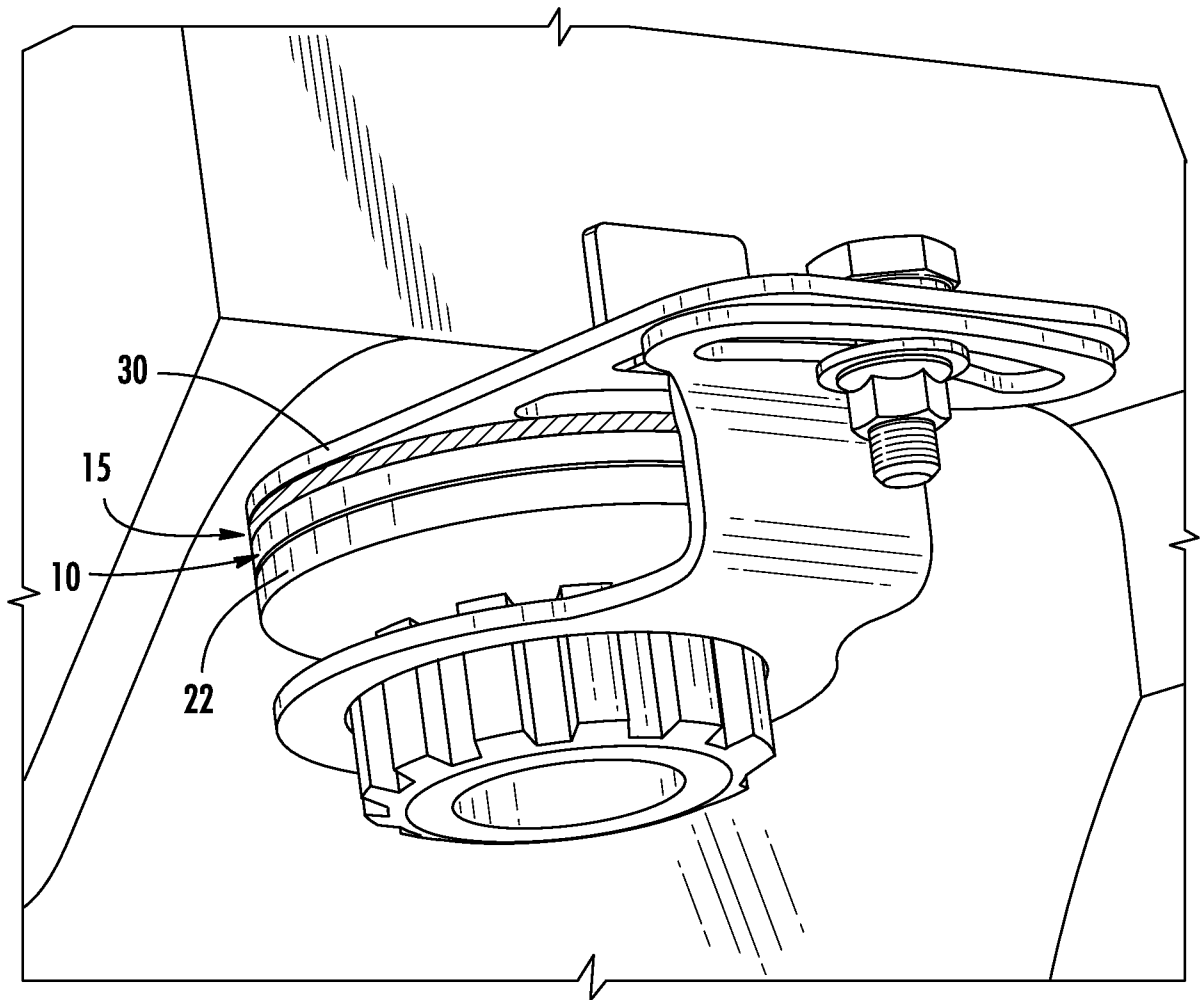


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/052805

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16B1/00 F16B43/00
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)

F16B

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)

EP0-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	DE 20 2005 003149 U1 (KIENMOSER HERMANN [DE]) 19 May 2005 (2005-05-19) figures 1-2 paragraphs [0001], [0027] - [0033] -----	1-20
X	GB 2 504 211 A (FORD GLOBAL TECH LLC [US]) 22 January 2014 (2014-01-22) figures 1-3a page 4, lines 5-26 -----	1-20
X	US 2011/158768 A1 (SCHRAER THORSTEN [DE]) 30 June 2011 (2011-06-30) figures 1-3 paragraphs [0018] - [0020] -----	1-20

☐ 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

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"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

8 December 2016

Date of mailing of the international search report

19/12/2016

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/052805

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