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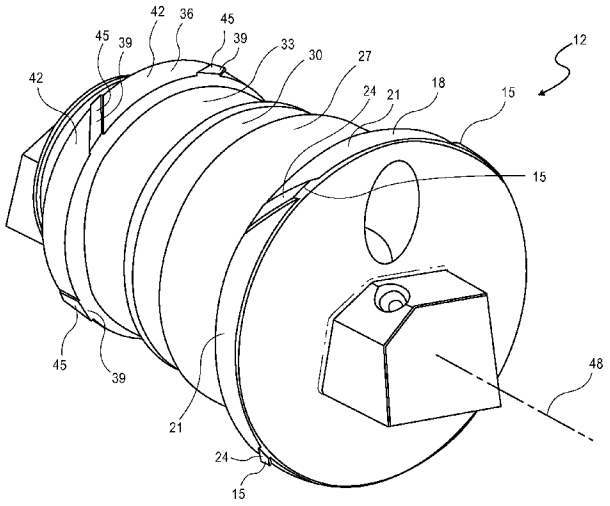
(54) Title: CUTTINGS REMOVAL WIPERS FOR CUTTER ASSEMBLIES AND METHOD



(57) Abstract: A wiper may be supported on at least one of a radially inwardly or radially outwardly facing dynamic interface surfaces of a pair surfaces on respective cutter journal and cutter shell. The wiper may be in the form of a low profile lug having a leading edge generally diagonally oriented relative to an axis of rotation of the cutter shell on the cutter journal. Thus, the leading edge of the wiper will move formation particles axially out from between the cutter journal and the cutter shell and away from a bearing seal. The wiper may have a height less than a regular clearance between the journal and the shell. A plurality of wipers may be supported on the dynamic interface surface of either the shell or the journal and may extend into close proximity to the oppositely facing dynamic interface surface of the other of the shell or the journal.

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CUTTINGS REMOVAL WIPERS FOR CUTTER ASSEMBLIES AND METHOD

BACKGROUND OF THE INVENTION

1. Technical Field

This invention generally relates to cutter assemblies including mechanisms for excluding or keeping debris and other formation particles away from bearings of the assemblies during earth boring.

2. State of the Art

Earth boring cutter assemblies have cutting heads with cutter shells that are rotatably supported on journals for rotation during boring operations. Due to the abrasive environment at a rock face being drilled and the confined volume in which the cuttings and other debris are held in close proximity to the cutter heads, entry of the cuttings and debris into the bearings of the cutter heads has been a problem that several have attempted to address in a variety of ways. In some instances, seals including o-rings and/or other ring-type seals have been incorporated to form a barrier between an interior and an exterior of the cutter heads. Bearings are held between bearing surfaces on respective cutter shells and journals of the cutter heads in an interior of the cutter heads and are protected from the abrasive environment on an exterior by the seals. However, the cuttings and debris still tend to enter the seals and reduce the rotational movement that these seals are intended to permit. The cuttings and debris can also damage or interfere with the seals so that the cuttings and debris can get into the bearings of the cutter heads and inhibit the rotational movement and/or damage the bearings.

In a specific example, a seal for a replaceable cutter that is used in the raise boring industry may typically be a mechanical face seal. As used in this industry, the

mechanical face seal is incorporated to seal the bearing lubricant in and exclude formation particles, which may include the cuttings and other debris. The face seal assembly is comprised of two metal seal rings and two o-rings forming two sets of a seal ring and an o-ring. The seal sets are assembled against each other, with the two seal rings each having a very flat dynamic seal surface. The o-ring provides and maintains a preload to the seal ring. It has been found, however, that contaminants produced during operation pack into the area adjacent to the seal rings and have the net effect of reducing the life of the seal.

DISCLOSURE OF THE INVENTION

There is a need for a device that sweeps cuttings and other debris away from the seals and bearings of cutter assemblies. The present invention generally relates to cutter assemblies which include mechanisms for removing debris during earth boring. More specifically, the subject invention is a cutter assembly for raise boring and other applications in which the cutter assembly has wipers on radially facing dynamic interface surfaces for sweeping cuttings away from seals and bearings of the assembly during earth boring.

In a simple form, one embodiment of the present invention may include a replaceable cutter assembly having a journal with at least one journal bearing surface and at least one radially outwardly facing dynamic journal interface surface. The cutter assembly may also have a cutter shell rotatably supported on the journal. The cutter shell may have a cutter shell bearing surface and at least one radially inwardly facing dynamic cutter shell interface surface. The cutter assembly may further include at least one wiper on the at least one of the interface surfaces of one of the journal and the cutter shell. The at least one wiper may thus be proximate to and face the at least one of the interface surfaces of the other of the journal and the cutter shell.

The wiper may be a low profile lug integrally formed on one of the journal and the cutter shell. A rotational axis of the cutter shell on the journal defines an axial direction. The wiper may have an edge that extends generally diagonally relative to the axial direction. Alternatively, the wiper may have an edge that extends generally helically relative to the axial direction.

The replaceable cutter assembly may have a plurality of wipers including the at least one wiper. The wipers may protrude radially from the at least one of the interface surfaces. The plurality of wipers may include four permanent low profile lugs circumferentially spaced from each other on the at least one of the dynamic journal interface surfaces relative to the rotational axis. The permanent low profile lugs further may have edges that extend generally diagonally relative to the axial direction.

The replaceable cutter assembly may further include at least one seal sealingly contacting the cutter shell and the cutter journal between the dynamic interface surfaces of the cutter shell and the cutter journal on one axial side and the bearing surfaces of the cutter shell and the cutter journal on another axial side of the at least one seal.

The replaceable cutter assembly may include a plurality of radially outwardly facing dynamic journal interface surfaces including the at least one radially outwardly facing dynamic journal interface surface. The replaceable cutter assembly may also include a plurality of radially inwardly facing dynamic cutter shell interface surfaces including the at least one radially inwardly facing dynamic cutter shell interface surface. The plurality of radially inwardly facing dynamic cutter shell interface surfaces may form respective pairs of interface surfaces with the plurality of radially outwardly facing dynamic journal interface surfaces. The assembly may have at least one of the wipers on at least one of the interface surfaces of each of the pairs of interface surfaces. Each of the at least one of the wipers may be proximate to and face the other of the interface surfaces of each of the pairs of the interface surfaces.

The present invention is believed to have patentable elements that are not limited to the entire assembly. As one example, the invention may encompass a replaceable cutter journal that may include a journal having at least one journal bearing surface and at least one radially outwardly facing dynamic journal interface surface. The cutter journal may have at least one wiper on the at least one interface surface.

The radially outwardly facing dynamic journal interface surface may have at least one first portion with a first diameter. The radially outwardly facing dynamic journal interface surface may have at least one second raised portion with a second diameter greater than the first diameter. The first and second portions may extend along a common circumferential line.

In the replaceable cutter journal, a rotational axis of the journal may define an axial direction. The radially outwardly facing dynamic journal interface surface may extend circumferentially and may be spaced proximally relative to the journal bearing surface in the axial direction.

The wiper may have an edge that extends generally diagonally relative to the axial direction. The replaceable cutter journal may have a plurality of wipers including the at least one wiper. The wipers may form second portions of the radially outwardly facing dynamic journal interface surface. The wipers may protrude radially from first portions of the at least one interface surface. The plurality of wipers may include four permanent low profile lugs circumferentially spaced from each other on the dynamic journal interface surface relative to the rotational axis. The permanent low profile lugs may have edges that extend generally diagonally relative to the axial direction.

The at least one second portion of the radially outwardly facing dynamic journal interface surface may include the at least one wiper integrally formed as one piece with the first portion of the radially outwardly facing dynamic journal interface surface.

The dynamic journal interface surface may be on a separable piece removably attached to the journal. The separable piece may have a seal retainer.

The replaceable cutter journal may include a plurality of radially outwardly facing dynamic journal interface surfaces including the at least one radially outwardly facing dynamic journal interface surface. Each of the radially outwardly facing dynamic journal interface surfaces may be on a separable piece removably attached to the rest of the journal.

In another aspect or embodiment, the present invention may encompass a replaceable cutter shell having at least one cutter shell bearing surface and at least one radially inwardly facing dynamic cutter shell interface surface. The replaceable cutter shell may also include at least one wiper on the at least one interface surface.

The radially inwardly facing dynamic cutter shell interface surface may have at least one first portion having a first diameter and at least one second raised portion having a second diameter less than the first diameter. The first and second portions may extend along a common circumferential line.

A rotational axis of the cutter shell may define an axial direction. The radially inwardly facing dynamic journal interface surface may extend circumferentially and may be spaced proximally relative to the cutter shell bearing surface in the axial direction.

The wiper may have an edge that extends generally diagonally relative to the axial direction. The replaceable cutter shell may include a plurality of wipers including the at least one wiper. The wipers may form second portions of the radially inwardly facing dynamic cutter shell interface surface. The wipers may protrude radially from first portions of the at least one interface surface. The plurality of wipers may include four permanent low profile lugs circumferentially spaced from each other on the dynamic cutter shell interface surface relative to the rotational axis.

The permanent low profile lugs may have edges that extend generally diagonally relative to the axial direction.

At least one second portion of the radially inwardly facing dynamic journal interface surface may include the at least one wiper integrally formed as one piece with the first portion of the radially inwardly facing dynamic journal interface surface.

In another aspect of the invention, a separate piece may be removably attachable to at least one of a cutter assembly journal or to a cutter assembly cutter shell. The separate piece may include a radially facing dynamic interface surface that may have at least a first portion and a second portion. The first and second portions may have respective first and second diameters different from each other. The first and second portions may extend along a common circumferential line. At least one of the first and second portions may form low profile lugs relative to the other of the first and second portions. The separate piece may have attachment structure for removably attaching the piece to at least one of the cutter assembly journal and the cutter assembly cutter shell. The separate piece may include a seal retainer with a seal retaining structure.

In another aspect, the present invention may include a method of inhibiting entry of debris into a cutter assembly. The method may include sweeping a first radially facing dynamic interface surface with at least one wiper disposed on a second oppositely radially facing dynamic interface surface. The method may also include moving debris axially away from at least one seal and at least one bearing of the cutter assembly. The steps of sweeping and moving may include automatically sweeping and moving during regular rotation of a cutter shell of the cutter assembly relative to a cutter journal of the cutter assembly. The steps of sweeping and moving may include presenting a leading edge of the at least one wiper transverse to an axial direction defined by an axis of rotation of the cutter shell relative to the cutter journal. The steps of sweeping and moving may include moving the leading edge of the at least one wiper circumferentially along the second oppositely radially facing dynamic interface surface.

The method may include sweeping a plurality of radially facing dynamic interface surfaces including the first radially facing dynamic interface surface with a plurality of wipers including the at least one wiper. The plurality of wipers may be disposed on a plurality of oppositely facing dynamic interface surfaces including the second oppositely radially facing dynamic interface surface. The method may include moving debris axially away from a plurality of seals including the at least one seal and moving debris axially away from a plurality of bearings including the at least one bearing of the cutter assembly. The steps of sweeping and moving may include automatically sweeping and moving during regular rotation of the cutter shell of the cutter assembly relative to the cutter journal of the cutter assembly.

The foregoing and other features and advantages of the present invention will be apparent from the following more detailed description of the particular embodiments of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a perspective view of a journal having wipers according to an embodiment of the present invention;

FIG. 1B is a sectional view at a central plane coincident with a rotational axis of a cutter assembly including a journal similar to the journal of Figure 1A according to an embodiment of the present invention;

FIG. 2 is a partial sectional view similar to Figure 1B showing a side view of the journal having wipers according to an embodiment of the present invention;

FIG. 3 is a detailed view of an area III of Figure 1B showing details of an alternative embodiment according to the present invention; and

FIG. 4 is a detailed view of an area IV of Figure 1B showing details of an alternative embodiment according to the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

As discussed above, embodiments of the present invention relate generally to cutter assemblies including mechanisms for excluding debris during earth boring.

Seals of a variety of types and configurations are known. For example, U.S. Patent No. 5,984,024 to Strand, is incorporated herein by reference as an example of a raise boring cutter assembly that uses a mechanical seal. U.S. Patent No. 6,033,117 to Cariveau et al., is also incorporated herein by reference as including a large variety of seal configurations that may additionally or alternatively be incorporated together with various cutter assemblies. While the present invention may be particularly useful in raise boring applications due to the relatively smaller amount of fluids utilized in cleaning and removing cuttings, it is to be understood that the teachings of this invention may be equally applied to other earth boring applications including those that incorporate pressurized fluids in cleaning and removing of cuttings.

Figure 1A is a perspective view of a journal 12 for a cutter assembly 13, (shown in Figure 1B and 2), for earth boring applications. The journal 12 may have wipers 15 in the form of low profile lugs or raised portions on a first radially outwardly facing dynamic journal interface surface 18. The dynamic journal interface surface 18 may have at least one first portion 21 and at least one second portion 24. The journal 12 has one or more bearing surfaces 27, 30, 33, and a second radially outwardly facing dynamic journal interface surface 36. The second radially outwardly facing dynamic journal interface surface 36 may have wipers 39, at least one first portion 42, and at least one second portion 45 similar to the first radially outwardly facing dynamic journal interface surface 18. The journal 12 may be supported together with the rest of the cutter assembly 13 in a saddle. U.S. Patent No. 5,984,024 to Strand shows and describes a number of saddle configurations.

As shown in the sectional view of Figure 1B, the wipers 15, 39 may be disposed on the cutter journal 12, as shown in Figure 1A, or alternatively on a cutter shell 16, as shown in dashed lines in Figure 1B. The wipers 15, 39 are in the form of

low profile lugs that are angled relative to an axis of rotation and central axis 48 of a cutter head shell 16 and cutter journal 12, respectively. The low profile lugs or wipers 15, 39 are shown on the dynamic interface surfaces 18, 36 between the cutter head cutter shell 16 and the cutter journal 12 and may be integral with either the cutter journal 12. Alternatively, the low profile lugs or wipers 15, 39 may be on an oppositely facing dynamic interface surface of the cutter shell 16. The low profile lugs or wipers 15, 39 are located exteriorly and adjacent to respective seals 51, 54 of the cutter shell 16. The lugs or wipers 15, 39 are angled so that relative motion between the cutter journal 15 and the cutter shell 16 sweeps debris axially out from between the journal 15 and the shell 16. The lugs or wipers 15, 39 are oriented to move formation particles including cuttings and other debris axially away from the seal as the cutter shell 16 rotates relative to the cutter journal 15 during use. In this way, the wipers 15, 39 also move the debris away from one or more bearings 57, 58, 59 and respective bearing surfaces 27, 30, 33, 61, 62, 63 in an interior of the cutter assembly 13.

As may be appreciated from the partial sectional view of Figure 2, a wiper 15, 39 may be formed on a dynamic interface surface 18, 36 of the journal 12 between a stationary component (journal 12) and a rotating component (cutter shell 16). The wiper 15, 39 is angled from the axis of rotation 48 of the two components in such a way that when the cutter shell is rotating in the normal "drilling" direction shown by arrow 66 in Figure 2, the formation particles including cuttings and other debris are swept out of the dynamic interface. Removing debris from the dynamic interface in this way keeps the area adjacent to the cutter seals 51, 54 much more clean and provides extended seal life. The wiper(s) can be formed by welding, machining, or other suitable methods.

The wipers 15 have leading edges 69 and the wipers 39 have leading edges 72 that confront the formation particles that are brought into contact therewith at least in part by the cutter shell and forces them out from between the cutter journal 15 and the cutter shell 16 in opposite directions as shown by arrows 75, 78. To this end, the leading edge, and the wipers 15, 39 in general, may be oriented at angles 81, 84 from

approximately ten degrees to approximately eighty degrees relative to the axis of rotation 48 or axial direction as shown. Alternatively, the angles 81, 84 may be in a range from approximately thirty to forty-five degrees inclusive. The angles may be inside or outside these ranges as long as they provide the function of moving the formation particles away from the seals 51, 54. As may be appreciated, if the wipers are supported on the cutter shell 16 and the direction of rotation 66 of the cutter shell 16 is the same, then the angle of the leading edges of the wipers 15, 39 will need to be slanted oppositely to those shown on the journal 12 in Figure 2 in order to sweep the formation particles out from between the cutter shell 16 and the cutter journal 15.

Referring back to Figure 1B, the heights 87, 88 of the wipers 15, 39 may be in a range from approximately one thirty-second of an inch to approximately one-half inch depending on an overall size of the cutter head and other factors. The heights 87, 88 may be approximately three sixteenths of an inch. These heights may be expressed as radial or diametric differences between the second portions 24, 45 and the first portions 21, 42 of the radially outwardly facing dynamic interface surfaces as shown and described with regard to Figure 1A. An alternative expression of the heights may be that the heights 87, 88 may be from approximately one tenth to approximately five times a width 91 of the wipers 15, 39. Although the drawing figures are not necessarily to scale, it is to be understood that similar proportions may be calculated by measurements and comparisons of the actual drawing element in Figures 1A-4. For example, the width of the wipers 15, 39 may be approximately one tenth the diameter of the dynamic interface surfaces on which the wipers 15, 39 are supported. It is to be understood that the proportion of the second portion of the dynamic surface relative to the first portion should generally be small, the proportion of the second and first portions may be varied. For example, while only four relatively narrow equally spaced wipers 15, 39 are shown equally spaced on a circumference of the dynamic surfaces at each end of the cutter journal 12, wider wipers may be incorporated. For example, it is contemplated that the width 91 of a wiper 15, 39 could be as much as approximately one half the circumference of the dynamic surfaces on which the wiper 15, 39 is supported.

It is to be understood that the wipers 15, 39 may, in many if not most cases, have the heights 87, 88 of a dimension smaller than regular clearances between the radially facing dynamic interface surfaces between the cutter assembly journals and cutter assembly cutter shells. Thus, customization of existing cutter assemblies may not be required other than steps to provide the wipers 15, 39 in accordance with the present invention.

For example, the first dynamic journal interface surface 18 shown in Figure 1 may be integral and form one piece with the rest of the cutter journal 12. Thus, the dynamic journal interface surface 18 may be machined together with the rest of the cutter journal 12 such as in a lathing process to integrally form the dynamic journal interface surface 18 at the larger diameter end of the journal 12 together with the bearing surfaces 27, 30, and 33. The wipers 15 may be added to a custom machined journal or may be added to a standard cutter journal such as by welding and shaping by a subsequent machining process, for example. Similarly, the radially outwardly facing dynamic journal interface surface 36 may be formed at the smaller diameter end of the journal 12. Alternatively, the interface surfaces may be formed on radially inwardly facing surfaces of the cutter shell. However, it is to be understood that in most cases on any given pair of mutually facing dynamic interface surfaces, the wipers may only be on one of the interface surfaces while the other of the surfaces remains smooth.

Figures 3 and 4 show detailed views of alternative embodiments of corresponding regions III and IV of the sectional view of Figure 1A. As may be appreciated, one or both of the dynamic interface surfaces may be added onto the cutter journal 12 and/or cutter shell 16. Figure 3 shows a sectional view of the region at the larger diameter end of the journal 12. Instead of the wiper 15 being one piece with the journal 12, the wiper is supported on a separable piece. While the separable piece may be any separable piece, Figure 3 shows the separable piece as a seal retainer 101 that is held by attaching structure to the journal 12. The attaching structure may include a notch 104 and groove 107 in the journal 12 and a retaining ring 110 received in the groove 107 and holding the retainer 101 in the notch 104. Additional structure

may include a slot on the retainer 101 and a dowel on the journal 12 and engaging the slot to inhibit rotation of the retainer 101 relative to the journal 12, for example. Alternatively or additionally, the attaching structure may be provided as a threaded connection between the separable piece and the journal. Further alternatively or additionally, the attaching structure may be provided by a slot and pin combination.

As shown, the seal retainer 101 has a seal retaining structure that may include a generally reentrant o-ring and seal ring capture recess 113. Another o-ring and seal ring recess is formed between the journal 12 and the cutter shell 16. Thus, a seal 117 having two seal rings 120 and two o-rings 123 may form a dynamic seal between the cutter journal 12 and the cutter shell 16. Advantageously, the seal retainer may have the dual function of retaining the seal 117 and supporting the wiper 15.

As shown in Figure 4, the wiper 39 may similarly be supported on a separable piece. While the separable piece may be any separable piece such as any annular segment of the journal or shell, Figure 4 shows the separable piece as a seal retainer 126 that is held by attaching structure to the journal 12. The attaching structure may include a notch 129 and groove 132 in the journal 12 and a retaining ring 135 received in the groove 132 and holding the retainer126 in the notch 129. Alternatively or additionally, the attaching structure may be provided as a threaded connection between the separable piece and the journal. Further alternatively or additionally, the attaching structure may be provided by a slot and pin combination. As shown and described with regard to Figure 3 above, the seal retainer 126 may have a seal retaining structure that may include a generally reentrant o-ring and seal ring capture recess 138. Another o-ring and seal ring recess may be formed between the journal 12 and the cutter shell 16. Thus, a seal 141 having two seal rings 144 and two o-rings 147 may form a dynamic seal between the cutter journal 12 and the cutter shell 16. Advantageously, the seal retainer may have the dual function of retaining the seal 141 and supporting the wiper 39.

It is contemplated that the separable piece may be provided as a press-in ring with wipers with or without seal retaining structure. This could be applied to either or both ends of the journal or the cutter shell as an annular segment. Alternatively or additionally, one or more separable pieces may have other configurations such as blocks having wipers or even as attachable wipers. The separable piece(s) may be attached to journals or cutter shells by one or more of set screws, pins, welding, tongue and groove structures enabling sliding in, or threads on the separable piece itself.

As described above, the wipers 15, 39 may be supported on either the journal 12 or on the cutter shell 16 as indicated by dashed lines in Figures 3 and 4. Additionally, the wipers 15, 39 may be supported on separable pieces that may be attached to the cutter shell 16 instead of the cutter journal 12. Any combination of these teachings is within the spirit and scope of the present invention. One configuration depicted in Figure 1A may have a combination of a first seal that may be installed without a separable seal retainer on a larger diameter end of the journal 12 and a second seal that may be installed and held in place by a separable seal retainer like that shown and described with regard to Figure 4 on a smaller diameter end of the journal 12. Thus, the installation of the seals and bearings may be facilitated.

It is to be understood that while the embodiments have been shown and described as having dynamic interface surfaces that generally define straight cylindrical surfaces that are parallel to the rotational axis 45 for each of the journal and the shell, and for the wipers 15, 39. That is, the interface surfaces are shown as being at a generally constant radius along their extent in a direction of the rotational axis 48, and the only differences in radii are between respective surfaces and between the surfaces and the wipers 15, 39. However, the dynamic interface surfaces may be angled relative to the rotational axis 48 in a range from approximately forty-five degrees radially inward toward the axis 48 from the inside of the shell 16 outward to approximately forty-five degrees radially outward from the inside of the shell 16 outward. As shown in Figure 1B, the angles would more typically extend radially inward toward the axis 48 only slightly from the inside outward for ranges 150, 153

from approximately ten degrees radially inward from an inside out to approximately thirty degrees radially outward from the inside out. Angles that correspond to the dynamic interface surfaces increasing in radius in a direction from the inside outward have the advantage of moving debris outward away from the seals 51 and 54 in a path of least resistance since the volume of space between the journal and the shell increases in an outward direction. Alternatively stated, incorporating increasing radii in outward directions of the shell and journal for the dynamic interface surfaces further inhibit packing of debris in an area near the seals 51 and 54. This advantage may be appreciated more when considering that the angles shown in two dimensions in Figure 1B really correspond to dynamic interface surfaces that are generally conically configured.

Solid arrow 156 represents a facing direction for a dynamic interface surface of the journal 12 that has a decreasing radius in an inward direction relative to the shell 16 and journal 12. Solid arrow 159 represents a facing direction for a radially outer surface of the wiper 39 on the dynamic interface surface with the facing direction 156. At an opposite end of the range of angles shown for the dynamic interface surfaces in Figure 1B, solid arrow 162 represents the facing direction of the dynamic interface surface of the journal 12 when the radius increases inwardly. The solid arrow 165 represents the facing direction for the radially outer surface of the wiper 39 on the dynamic interface surface with the facing direction 162. As set forth above, the corresponding dynamic interface surface on the shell would generally match in shape and be only slightly larger than the corresponding interface surface and wiper(s) of the journal for any angle within the range.

Dashed arrow 168 represents a facing direction for a dynamic interface surface of the shell 16 that has a decreasing radius in an inward direction relative to the shell 16 and journal 12. Dashed arrow 171 represents a facing direction for a radially inner surface of the wiper 39 as applied on the dynamic interface surface with the facing direction 168. At an opposite end of the range of angles shown for the dynamic interface surfaces in Figure 1B, dashed arrow 174 represents the facing direction of the dynamic interface surface of the shell 12 when the radius increases inwardly. The

dashed arrow 177 represents the facing direction for the radially outer surface of the wiper 39 as applied on the dynamic interface surface with the facing direction 174. As set forth above, the corresponding dynamic interface surface on the journal 12 would generally match in shape and be only slightly smaller than the corresponding interface surface and wiper(s) as applied to the shell 16 for any angle within the range.

It is to be understood that the ranges of angles for the dynamic interface surfaces relative to the rotational axis 48 described above may be applied to both ends of the journal 12 and shell 16 assembly. Furthermore, the ranges of angles may be applied to separable pieces that are coupled to one or both of the journal and shell in accordance with the embodiments shown in Figures 3 and 4.

The embodiments and examples set forth herein were presented in order to best explain the present invention and its practical application and to thereby enable those of ordinary skill in the art to make and use the invention. However, those of ordinary skill in the art will recognize that the foregoing description and examples have been presented for the purposes of illustration and example only. The description as set forth is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the teachings above without departing from the spirit and scope of the forthcoming claims. For example, while the wipers have been shown and described as facing radially, it is contemplated that a similar advantage may be achieved with wipers that face at an angle other than normal to a radial direction. Wipers on dynamic interface surfaces that face between zero and ninety degrees relative to a radial direction are considered to be within the scope of the present invention. The dynamic interface surfaces and/or the wipers are considered to be radially facing when there is a radial component to the direction in which they face.

CLAIMS

1. A replaceable cutter assembly comprising:

a journal having at least one journal bearing surface, the journal having at least one radially outwardly facing dynamic journal interface surface;

a cutter shell rotatably supported on the journal, the cutter shell having a cutter shell bearing surface and the cutter shell having at least one radially inwardly facing dynamic cutter shell interface surface; and

at least one wiper on the at least one of the interface surfaces of one of the journal and the cutter shell;

wherein the at least one wiper is proximate to and faces the at least one of the interface surfaces of the other of the journal and the cutter shell.

2. The replaceable cutter assembly of claim 1, wherein the wiper is a low profile lug integrally formed on one of the journal and the cutter shell.

3. The replaceable cutter assembly of claim 1, wherein:

a rotational axis of the cutter shell on the journal defines an axial direction; and

the wiper has an edge that extends generally diagonally relative to the axial direction.

4. The replaceable cutter assembly of claim 1, wherein:

a rotational axis of the cutter shell on the journal defines an axial direction; and

the wiper has an edge that extends generally helically relative to the axial direction.

5. The replaceable cutter assembly of claim 1, further comprising a plurality of wipers may include the at least one wiper, wherein the wipers protrude radially from the at least one of the interface surfaces.

6. The replaceable cutter assembly of claim 5, wherein a rotational axis of the cutter shell defines an axial direction, the plurality of wipers comprises four permanent low profile lugs circumferentially spaced from each other on the at least one of the dynamic journal interface surfaces relative to the rotational axis, wherein the permanent low profile lugs further comprise edges that extend generally diagonally relative to the axial direction.

7. The replaceable cutter assembly of claim 1, further comprising at least one seal sealingly contacting the cutter shell and the cutter journal between the dynamic interface surfaces of the cutter shell and the cutter journal on one axial side and the bearing surfaces of the cutter shell and the cutter journal on another axial side of the at least one seal.

8. The replaceable cutter assembly of claim 1, further comprising:

a plurality of radially outwardly facing dynamic journal interface surfaces including the at least one radially outwardly facing dynamic journal interface surface;

a plurality of radially inwardly facing dynamic cutter shell interface surfaces including the at least one radially inwardly facing dynamic cutter shell interface surface, the plurality of radially inwardly facing dynamic cutter shell interface surfaces forming respective pairs of interface surfaces with the plurality of radially outwardly facing dynamic journal interface surfaces; and

at least one of the wipers on at least one of the interface surfaces of each of the pairs of interface surfaces;

wherein each of the at least one of the wipers is proximate to and faces the other of the interface surfaces of each of the pairs of the interface surfaces.

9. A replaceable cutter journal comprising:

a journal having at least one journal bearing surface and at least one radially outwardly facing dynamic journal interface surface; and

at least one wiper on the at least one interface surface.

10. The replaceable cutter journal of claim 9, wherein the radially outwardly facing dynamic journal interface surface comprises:

at least one first portion having a first diameter; and

at least one second raised portion having a second diameter greater than the first diameter;

wherein the first and second portions extend along a common circumferential line.

11. The replaceable cutter journal of claim 9, wherein:

a rotational axis of the journal defines an axial direction; and

the radially outwardly facing dynamic journal interface surface extends circumferentially and is spaced proximally relative to the journal bearing surface in the axial direction.

12. The replaceable cutter journal of claim 9, wherein:

a rotational axis of the journal defines an axial direction; and

the wiper has an edge that extends generally diagonally relative to the axial direction.

13. The replaceable cutter journal of claim 9, further comprising a plurality of wipers including the at least one wiper, wherein:

the wipers form second portions of the radially outwardly facing dynamic journal interface surface; and

the wipers protrude radially from first portions of the at least one interface surface.

14. The replaceable cutter journal of claim 13, wherein a rotational axis of the cutter shell defines an axial direction, the plurality of wipers comprises four permanent low profile lugs circumferentially spaced from each other on the dynamic journal interface surface relative to the rotational axis, wherein the permanent low profile lugs further comprise edges that extend generally diagonally relative to the axial direction.

15. The replaceable cutter journal of claim 9, wherein at least one second portion of the radially outwardly facing dynamic journal interface surface comprises the at least one wiper integrally formed as one piece with a first portion of the radially outwardly facing dynamic journal interface surface.

16. The replaceable cutter journal of claim 9, wherein the dynamic journal interface surface is on a separable piece removably attached to the journal.

17. The replaceable cutter journal of claim 16, wherein the separable piece comprises a seal retainer.

18. The replaceable cutter journal of claim 9, further comprising a plurality of radially outwardly facing dynamic journal interface surfaces including the at least one radially outwardly facing dynamic journal interface surface.

19. The replaceable cutter journal of claim 18, wherein each of the radially outwardly facing dynamic journal interface surfaces is on a separable piece removably attached to a remainder of the journal.

20. A replaceable cutter shell comprising:

a cutter shell having at least one cutter shell bearing surface and at least one radially inwardly facing dynamic cutter shell interface surface; and

at least one wiper on the at least one interface surface.

21. The replaceable cutter shell of claim 20, wherein the radially inwardly facing dynamic cutter shell interface surface comprises:

at least one first portion having a first diameter; and

at least one second raised portion having a second diameter less than the first diameter;

wherein the first and second portions extend along a common circumferential line.

22. The replaceable cutter shell of claim 20, wherein:

a rotational axis of the cutter shell defines an axial direction; and

the radially inwardly facing dynamic journal interface surface extends circumferentially and is spaced proximally relative to the cutter shell bearing surface in the axial direction.

23. The replaceable cutter shell of claim 20, wherein:

a rotational axis of the cutter shell defines an axial direction; and

the wiper has an edge that extends generally diagonally relative to the axial direction.

24. The replaceable cutter shell of claim 20, further comprising a plurality of wipers including the at least one wiper, wherein:

the wipers form second portions of the radially inwardly facing dynamic cutter shell interface surface; and

the wipers protrude radially from first portions of the at least one interface surface.

25. The replaceable cutter shell of claim 24, wherein a rotational axis of the cutter shell defines an axial direction, the plurality of wipers comprises four permanent low profile lugs circumferentially spaced from each other on the dynamic cutter shell interface surface relative to the rotational axis, wherein the permanent low profile lugs further comprise edges that extend generally diagonally relative to the axial direction.

26. The replaceable cutter shell of claim 20, wherein at least one second portion of the radially inwardly facing dynamic journal interface surface comprises the at least one wiper integrally formed as one piece with a first portion of the radially inwardly facing dynamic journal interface surface.

27. A separate piece removably attachable to at least one of a cutter assembly journal or a cutter assembly cutter shell, the separate piece comprising:

a radially facing dynamic interface surface having at least a first portion and a second portion, the first and second portions having respective first and second diameters different from each other, the first and second portions extending along a common circumferential line; and

attachment structure on the separate piece for removably attaching the piece to at least one of a cutter assembly cutter journal and a cutter assembly cutter shell.

28. The separate piece of claim 27, wherein the separate piece comprises a seal retainer having a seal retaining structure.

29. The separate piece of claim 27, wherein at least one of the first and second portions forms low profile lugs relative to the other of the first and second portions.

30. A method of inhibiting entry of debris into a raise bore cutter assembly, the method comprising:

sweeping a first radially facing dynamic interface surface with at least one wiper disposed on a second oppositely radially facing dynamic interface surface; and

moving debris axially away from at least one seal and at least one bearing of the cutter assembly;

wherein the steps of sweeping and moving comprise automatically sweeping and moving during regular rotation of a cutter shell of the cutter assembly relative to a cutter journal of the cutter assembly.

31. The method of claim 30, wherein the steps of sweeping and moving comprise:

presenting a leading edge of the at least one wiper transverse to an axial direction defined by an axis of rotation of the cutter shell relative to the cutter journal; and

moving the leading edge of the at least one wiper circumferentially along the second oppositely radially facing dynamic interface surface.

32. The method of claim 30, further comprising:

sweeping a plurality of radially facing dynamic interface surfaces including the first radially facing dynamic interface surface with a plurality of wipers including the at least one wiper, the plurality of wipers disposed on a plurality of oppositely facing dynamic interface surfaces including the second oppositely radially facing dynamic interface surface; and

moving debris axially away from a plurality of seals including the at least one seal and moving debris axially away from a plurality of bearings including the at least one bearing of the cutter assembly;

wherein the steps of sweeping and moving comprise automatically sweeping and moving during regular rotation of the cutter shell of the cutter assembly relative to the cutter journal of the cutter assembly.

* * * *

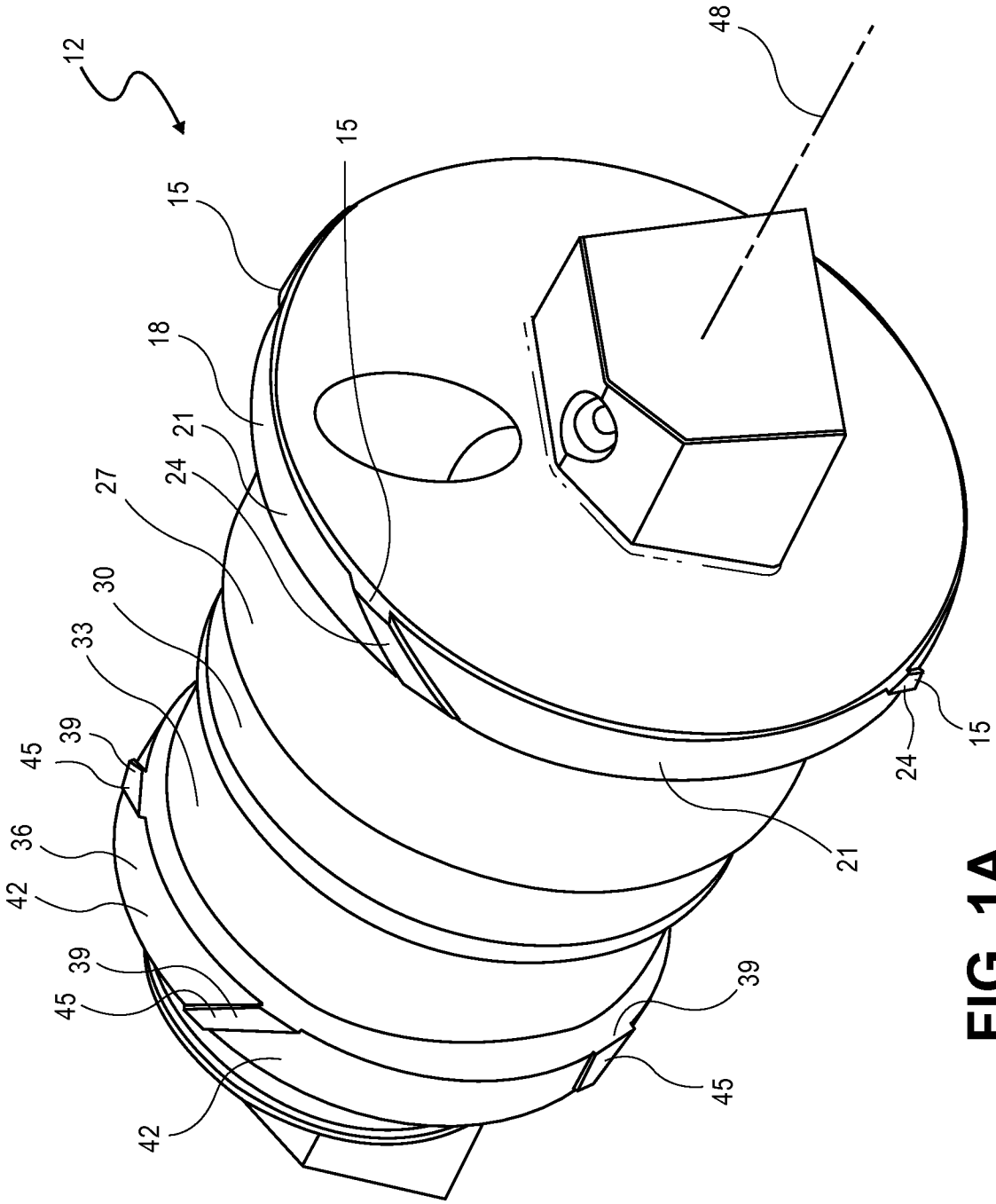

FIG. 1A

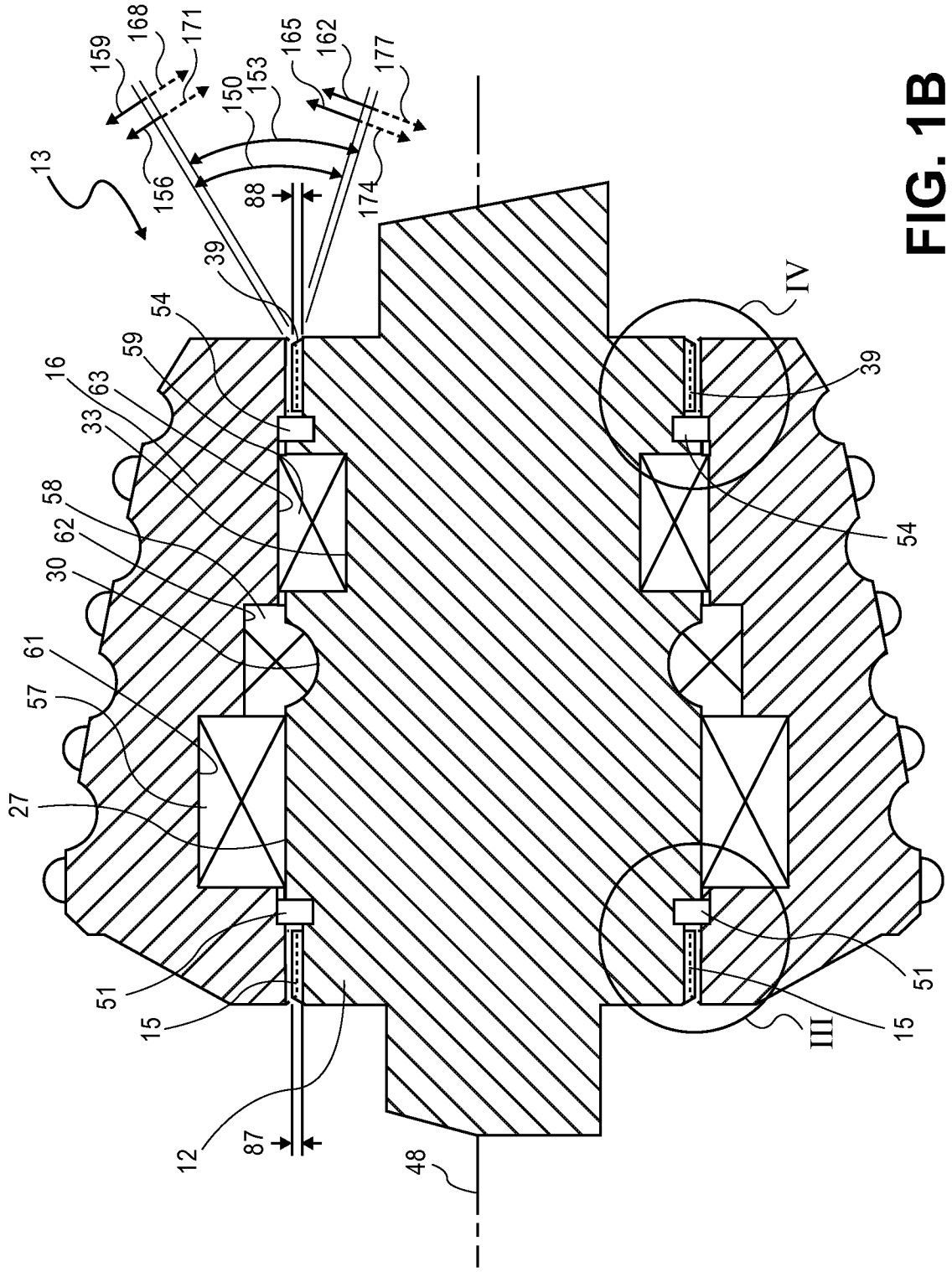
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FIG. 1B

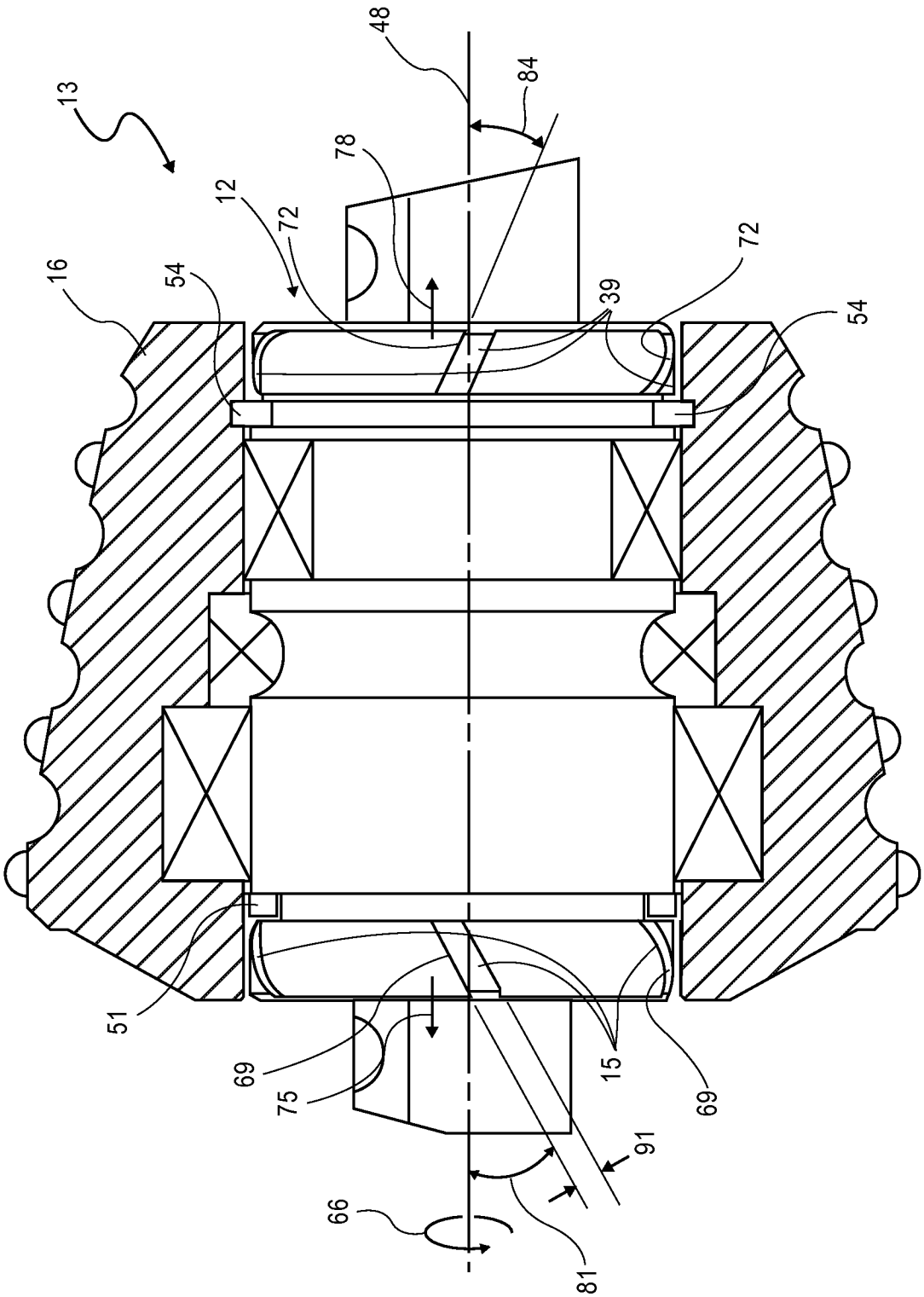

FIG. 2

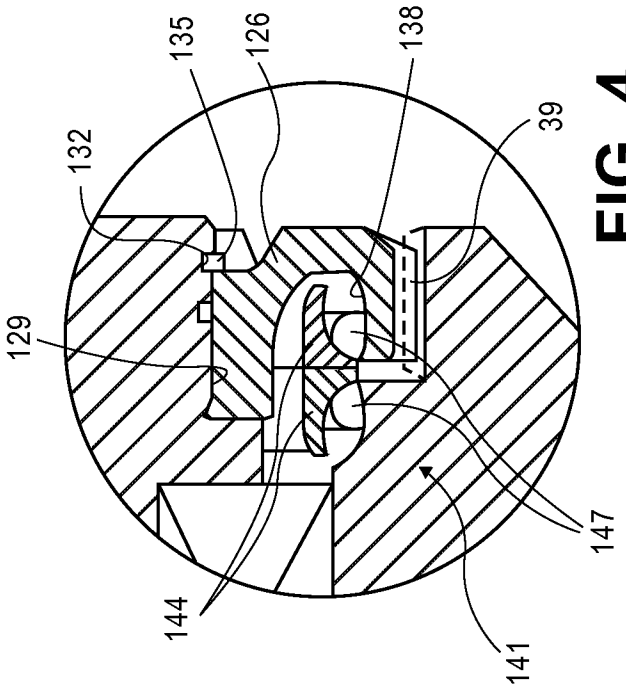
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FIG. 4

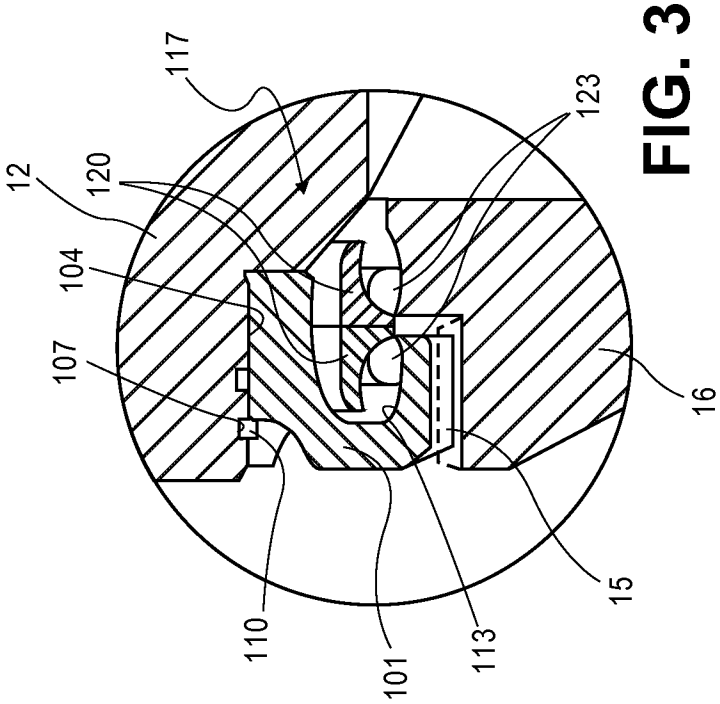
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FIG. 3