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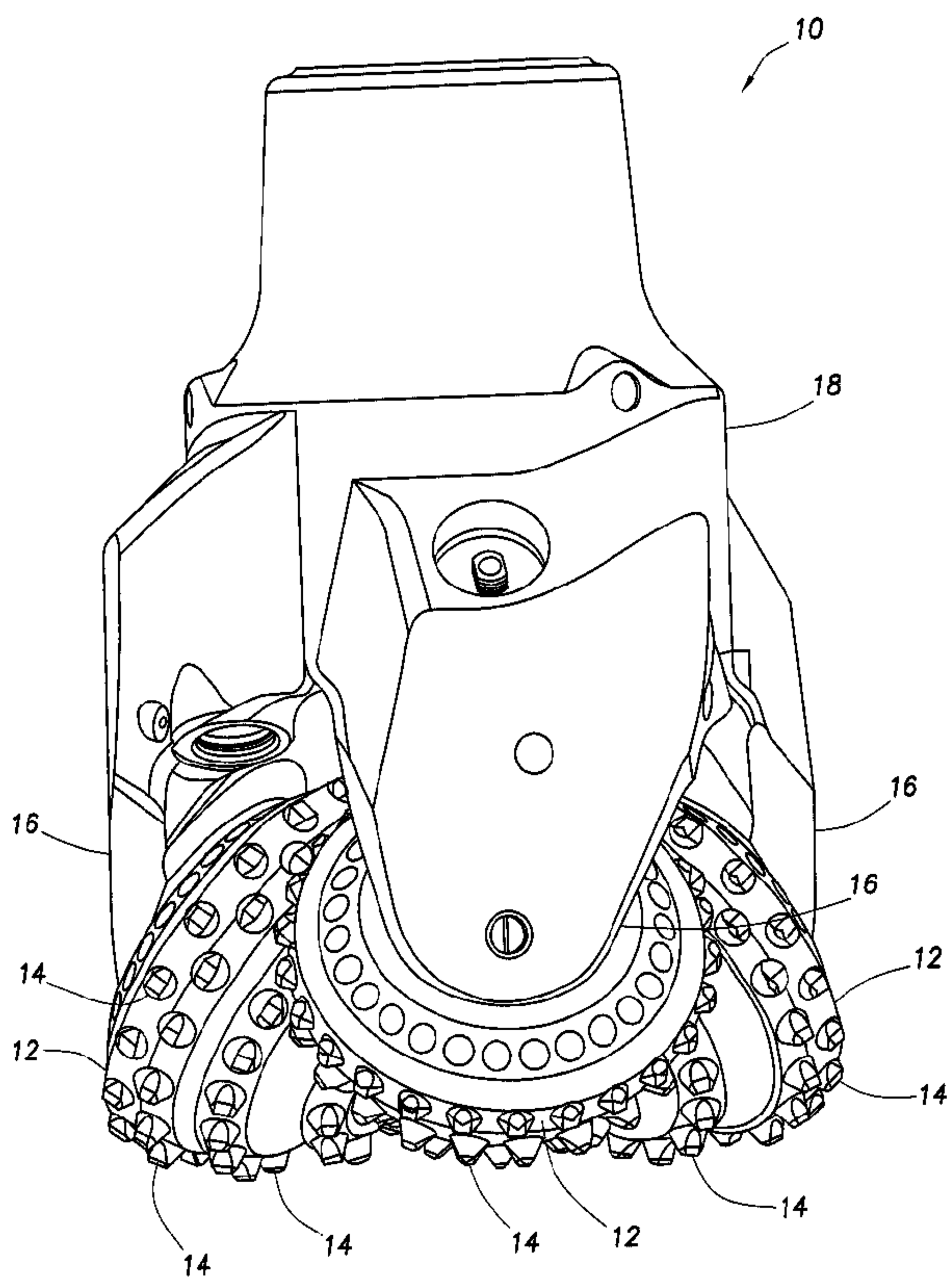
(54) Titre : REDUCTION DE PRESSION DE CONTACT ENTRE PALIERS DE TREPAN

(54) Title: DRILL BIT BEARING CONTACT PRESSURE REDUCTION



(57) Abrégé/Abstract:
A method of reducing contact pressure between bearing surfaces of a drill bit can include constructing a structure which supports one bearing surface in contact with the other bearing surface, and reducing contact pressure between the bearing surfaces by relieving strain energy in the structure. A drill bit can include one bearing surface which contacts another bearing surface. There is a transition between contact and lack of contact between the bearing surfaces. A structure supporting one of the bearing surfaces has a reduced stiffness, whereby a contact pressure between the bearing surfaces is reduced at the transition.

ABSTRACT

A method of reducing contact pressure between bearing surfaces of a drill bit can include constructing a structure which supports one bearing surface in contact with the other bearing surface, and reducing contact pressure between the bearing surfaces by relieving strain energy in the structure. A drill bit can include one bearing surface which contacts another bearing surface. There is a transition between contact and lack of contact between the bearing surfaces. A structure supporting one of the bearing surfaces has a reduced stiffness, whereby a contact pressure between the bearing surfaces is reduced at the transition.

DRILL BIT BEARING CONTACT PRESSURE REDUCTION

TECHNICAL FIELD

This disclosure relates generally to equipment utilized and operations performed in conjunction with subterranean wells and, in an example described below, more particularly provides for drill bit bearing contact pressure reduction.

BACKGROUND

Bearing failure is one of the main problems affecting conventional drill bits used to drill subterranean wells. Such failures will generally require that the drill bits be retrieved for replacement, resulting in substantial loss of time and money.

Bearing failures can be due to a variety of factors. However, if the maximum contact pressure between bearing surfaces could be substantially reduced, bearing failures could also be reduced significantly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of a drill bit embodying principles of the present disclosure.

FIG. 2 is a cross-sectional view through one arm of the drill bit of FIG. 1.

FIG. 3 is an enlarged scale schematic cross-sectional view of a portion of an interface between bearing surfaces of the drill bit.

FIG. 4 is graph of modeled contact pressure versus distance along a journal for modified and unmodified cone/journal surface interfaces.

FIGS. 5-14 are schematic cross-sectional views of various strain energy-relieving configurations for interfaces between bearing surfaces.

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a drill bit 10 which can embody principles of this disclosure. The drill bit 10 is of the type known to those skilled in the art as a roller cone bit or a three-cone bit, due to its use of multiple generally conical rollers or cones 12 having earth-engaging cutting elements 14 thereon.

Each of the cones 12 is rotatably secured to a respective arm 16 extending downwardly (as depicted in FIG. 1) from a main body 18 of the bit 10. In this example, there are three each of the cones 12 and arms 16.

However, it should be clearly understood that the principles of this disclosure may be incorporated into drill bits having other numbers of cones and arms, and other types of drill bit configurations. The roller cone drill bit 10 depicted in FIG. 1 is merely one example of a wide variety of drill bit types which can utilize the principles described herein.

Referring additionally now to FIG. 2, a cross-sectional view of one of the arms 16 is representatively illustrated. In this view it may be seen that the cone 12 rotates about a journal 20 of the arm 16. Retaining balls 22 are used between the cone 12 and the journal 20 to secure the cone on the arm 16.

Lubricant is supplied to the interface between the cone 12 and the journal 20 from a chamber 24 via a passage 26. A pressure equalizing device 28 ensures that the lubricant is at substantially the same pressure as the downhole environment when the drill bit 10 is being used to drill a wellbore.

A seal 30 is used to prevent debris and well fluids from entering the interface between the cone 12 and the journal 20, and to prevent escape of the lubricant from the interface area. As the cone 12 rotates about the journal 20, the seal 30 preferably rotates with the cone and seals against an outer surface of the journal.

The seal 30 is retained in an annular groove 38 (also known to those skilled in the art as a seal "gland") formed radially outward from an inner cylindrical bearing surface 32 in the cone 12. The seal 30 seals against an outer cylindrical bearing surface 44 on the journal 20.

Although the retaining balls 22 retain the cone 12 on the journal 20, they do not resist the large forces exerted on the cone during drilling. Instead, contact between the surfaces 32, 44, as well as contact between pairs of other bearing surfaces 34, 36, 40, 42, operate to resist the enormous loads acting on the cone 12 as it rotates on the journal 20 during drilling. Each pair of surfaces (32 and 44; 34 and 36; 40 and 42) functions as a type of plain bearing which permits substantially unhindered rotation of the cone 12 about the journal 20, while transmitting large forces between the arm 16 and the cone.

One problem with conventional drill bit bearing designs is that, at transitions in the bearing surfaces, very high contact pressures can be experienced. These very high contact pressures cause considerable material loss on parts due to sliding wear and, in extreme cases, can result in premature failure of the bearing surfaces, thereby reducing or destroying the effectiveness of the drill bit 10 in the drilling operation, requiring replacement of the bit, and thereby causing loss of time and money in a drilling operation. Fortunately, these drawbacks of conventional drill bit bearing designs can be minimized or eliminated by employing the principles described in this disclosure.

Referring additionally now to FIG. 3, an enlarged scale cross-sectional view of the seal groove 38 and adjacent bearing surfaces 32, 44 is representatively illustrated. In this view it may be seen that a transition in the surface 32 occurs at a radius 50 formed between the surface and a side wall 52 of the groove 38. The wall 52 is oriented orthogonal to an axis of rotation 53 (see FIG. 2) of the cone 12 about the journal 20.

The present inventor has discovered via modeling techniques that contact pressure between the surfaces 32, 44 is highly concentrated at the transition between the surface 32 and the side wall 52. More specifically, the modeling techniques have revealed that, under certain circumstances, contact pressure near a tangent 54 (i.e., the transition between a) contact between the surfaces 32, 44 and b) lack of contact between the surfaces) can be many times the contact pressure away from the tangent. Note that, for clarity of illustration and description, the surfaces 32, 44 are depicted in FIG. 3 as being spaced apart somewhat, but the surfaces would contact each other when forces 56 are being transmitted between the cone 12 and journal 20.

The inventor's analysis has also revealed that contact pressure on most of (e.g., ~90% of) the surface area of contact between the surfaces 32, 44 can be much less than (e.g., ~20% of) the contact pressure at the transition between the surface 32 and the side wall 52. This phenomenon is known as "edge loading" in the art of contact mechanics.

The underlying reason for this circumstance is the concentrated accumulation of strain energy in the structure of the cone 12 adjacent the transition between the surface 32 and the side wall 52. If this strain energy could be relieved, the contact pressure at the transition could be reduced, resulting in the contact pressure being more evenly distributed across the area of contact between the surfaces 32, 44.

One technique for relieving the strain energy at the transition in the surface 32 is depicted in FIG. 3. Note that material has been removed from the cone 12 to thereby form an annular recess 58 extending axially from the side wall 52. One of the beneficial results of the recess 58 is a reduction in the stiffness of the structure 60 adjacent the tangent 54.

This reduction in stiffness allows the structure 60 to flex somewhat, thereby relieving strain energy. That is, the strain energy in the structure 60 will be reduced relative to what the strain energy in the structure 60 would have been if it had been constructed similar to an adjacent structure 74 of the cone 12 which does not have the recess 58 formed therein. Transmission of the forces 56 through the structure 60 will result in much greater deflection of the structure 60, as compared to deflection of the adjacent structure 74 due to transmission of the forces.

The recess 58 may be in the form of a groove, slit, depression, etc. In the example of FIG. 3, the recess 58 extends completely around in the structure 60, so that the stiffness of the structure is reduced circumferentially about the bearing surface 32. In other examples, the reduction in stiffness of a structure may not extend completely around the interior or exterior of the structure. Particularly where loading on the structure is typically from one direction (for example, in non-rotating elements, such as the journal 20), it may be desirable to reduce the stiffness of the structure only on one side of the structure.

In FIG. 4, a graph of contact pressure versus distance along the journal 20 is representatively illustrated. This graph represents one of the results of the inventor's modeling efforts discussed above.

One curve 62 on the graph represents contact pressure along the journal 20 with an unmodified cone 12, that is, the cone without the recess 58 formed therein to reduce the stiffness of the structure 60. Another curve 64 on the graph represents contact pressure along the journal 20 with the cone 12 modified as described above to relieve the strain energy in the structure 60.

Note that the maximum contact pressure 66 for the unmodified cone 12 is many times greater than the maximum contact pressure 68 for the modified cone 12. A contact pressure 70 at the remainder of the cone/journal interface for the unmodified design (i.e., adjacent the relatively high stiffness structure 74) appears to be somewhat less than a contact pressure 72 at the remainder of the cone/journal interface for the modified design, but both of these contact pressures 70, 72 are much less than the maximum contact pressure 66 for the unmodified design.

The maximum contact pressure 68 for the modified design at the transition on the surface 32 is only slightly more than the contact pressures 70, 72 at the remainder of the cone 12/journal 20 interface, and is much less than the maximum contact pressure 66 for the unmodified design. Thus, it is expected that drill bits constructed using the principles described in this disclosure will have much greater bearing longevity.

Although the recess 58 is depicted as being used in FIG. 3 for reducing the stiffness of the structure 60 adjacent the tangent 54 between the surfaces 32, 44, it should be understood that other means of reducing stiffness at transitions can be used, without departing from the principles of the present disclosure. These other means can be used to permit the structure 60 to distort near the transition (e.g., near the tangent 54) and thereby relieve strain energy and reduce contact pressure between the surfaces 32, 44. Such other means could include, for example, hole(s) 78 (see FIG. 5), void(s) 80 (see FIG. 6), reduced stiffness structure(s) 82 (see FIG. 7; wherein the reduced stiffness may be due to various features, such as, use of a reduced modulus material, lack of material, etc.), reduced elastic modulus material(s) 84 (see FIG. 8), etc., and any combination of contact pressure reducing means.

If a reduced elastic modulus material 84 is used, in some examples the elastic modulus of the material may vary gradually. Thus, the reduced elastic modulus material 84 may have "gradient" modulus properties. Such a gradient elastic modulus material or functionally gradient material (see FIG. 11) can be used to smooth out a transition in stiffness, to thereby provide a gradual drop in contact pressure between the surfaces 32, 44.

The material 84 can incorporate nano structures 76 therein to provide the reduced elastic modulus of the material. As known to those skilled in the art, a nano structure is a structure having a maximum size of 100 nm. As used herein, the term "nano structure" can encompass nano particles, nano tubes, and any other structures having a size of 100 nm or less.

In FIG. 9, the structure 60 comprises a sleeve bearing which is interference fit within the cone 12. Thus, the bearing surface 32 which contacts the bearing surface 44 is formed on an interior of the sleeve bearing. In this example, the sleeve bearing has the radius 50 formed thereon, so that a transition between contact and lack of contact between the bearing surfaces 32, 44 occurs at the tangent 54. The recess 58 is formed into the structure 60 to relieve strain energy at the transition between contact and lack of contact between the surfaces 32, 44. The recess 58 reduces the stiffness of the structure 60 supporting the surface 32 at the tangent 54, thereby reducing the maximum contact pressure between the surfaces 32, 44.

In FIG. 10, the structure 60 comprises a floating thrust bearing 86 disposed between bearing surfaces 40, 42 on the cone 12 and the journal 20. Note that the radius 50 is not formed on the structure 60 in this example, but the recess 58 still reduces the stiffness of the structure 60 at a transition between contact and lack of contact between the bearing surfaces 40, 42 and respective bearing surfaces 88, 90 on the thrust bearing 86.

The configuration of FIG. 10 demonstrates that the principles of this disclosure may be implemented even though the radius 50 and tangent 54 are not formed on the structure 60, and even though the structure is not part of the cone 12. This example also demonstrates that the principles of this disclosure can be applied to various different types of bearing surfaces.

The thrust bearing 86 could utilize any of the techniques described herein for reducing contact pressure between bearing surfaces. For example, nano structures 76, holes 78, voids 80, reduced modulus materials 84, functionally gradient materials 92, multiple materials 160, 162, etc. could be used in the thrust bearing 86, if desired.

The recess 58 is depicted in FIGS. 3, 9 & 10 as being annular-shaped. However, other shapes could be used in keeping with the principles of this disclosure. The above disclosure describes reducing stiffness of the structure 60 supporting the surface 32, but it should be clearly understood that the principles of this disclosure can be used for reducing the stiffness of any structure supporting any of the other surfaces 34, 36, 40, 42, 44, or any other surfaces, or any combination of surfaces.

Although the principles of this disclosure have been described above as being used to reduce contact pressure at the interface between the surfaces 32, 44 near the tangent 54, those principles can be applied at other locations in the drill bit 10, and in other types of equipment. For example, the principles of this disclosure could be used at the interfaces between other pairs of surfaces, such as between surfaces 34 and 36, and between surfaces 40 and 42.

Note that the surfaces 32, 44 are interrupted by annular recesses for receiving the retaining balls 22. However, the surfaces 32, 44 continue on opposite sides of the retaining balls 22, and the principles of this disclosure can be utilized for reducing contact pressure between the surfaces on either side of the retaining balls.

The above disclosure describes reducing the stiffness of the structure 60 supporting the bearing surface 32 on the cone 12. However, the principles of this disclosure can also, or alternatively, be used to reduce the stiffness of structures supporting bearing surface 44 on the journal 20, bearing surface 42 on the journal, bearing surface 40 on the cone, bearing surface 34 on the cone, or bearing surface 36 on the journal. If the techniques described in this disclosure are used for reducing the stiffness of a structure supporting a bearing surface on the journal 20, then it is not typically necessary for the reduction in stiffness to extend completely around the journal, since maximum contact pressure is typically experienced on only one side of the journal.

Referring additionally now to FIG. 11, another configuration of the drill bit 10 is representatively illustrated, in which a functionally gradient material 92 provides a reduced stiffness to the structure 60 and an increased stiffness to the structure 74. The material 92 may have a reduced modulus at the structure 60 and an increased modulus at the structure 74, thereby providing for reduced contact pressure at the transition between contact and lack of contact between the bearing surfaces 32, 44.

Referring additionally now to FIG. 12, another configuration of the drill bit 10 is representatively illustrated, in which the cone 12 has the functionally gradient material 92 incorporated therein, so that there is a gradual transition from the reduced stiffness structure 60 to the increased stiffness structure 74 in the cone itself. This will result in reduced contact pressure at the transition between contact and lack of contact between the bearing surfaces 32, 44. The functionally gradient material 92 could also, or alternatively be incorporated into the journal 20, if desired.

Referring additionally now to FIG. 13, a cross-sectional view of the journal 20 is representatively illustrated for yet another configuration of the drill bit 10. In this configuration, the functionally gradient material 92 is used on a lower side of the journal bearing surface 44. It will be appreciated that this side of the journal 20 receives the maximum contact pressure due to forces applied to the journal, and so it may be desired to only utilize the functionally gradient material 92 on the lower side where it would be most advantageous for reducing contact pressure between the bearing surfaces 44, 32.

In the configurations of FIGS. 11-13, the functionally gradient material 92 can reduce contact pressure between the bearing surfaces 32, 44 at the transition between contact and lack of contact between the bearing surfaces 32, 44. This is due to the material 92 providing a reduced stiffness in the structure 60 and an increased stiffness in the structure 74. For example, the material 92 may have a reduced modulus at the structure 60 and an increased modulus at the structure 74, thereby providing for reduced contact pressure at the transition between contact and lack of contact between the bearing surfaces 32, 44.

Such a change in stiffness and/or modulus can be accomplished in other ways, in keeping with the principles of this disclosure. In one example depicted in FIG. 14, multiple materials 160, 162 could be used, with one material 160 having a reduced stiffness and/or modulus in the structure 60, and another material 162 having an increased stiffness and/or modulus in the structure 74. The transition from the first material 160 to the second material 162 could be gradual (such as, by tapering from one to the other as depicted in FIG. 14), and could be provided in a separate bearing sleeve 164 or as part of either or both of the components 12, 20. For example, the material 160 could be a less rigid material (such as silver, etc.) and the material 162 could be a more rigid material (such as hardened steel, etc.).

It may now be fully appreciated that the above disclosure provides several advancements to the art of reducing contact pressures in equipment such as drill bits. The principles of this disclosure result in dramatic reductions in maximum contact pressure between bearing surfaces, and can do so without requiring that any additional components be added to the equipment, and without requiring that extensive redesign be implemented.

The principles of this disclosure can be applied *in-situ* in a non-intrusive manner in some examples. The resulting structures can also be easily inspected for conformance to specifications.

Due to the reduced maximum contact pressure, a variety of different types of lubricants can be used in the drill bit 10.

For example, oil could be used as a lubricant, instead of conventional grease.

The above disclosure provides to the art an improved method of reducing contact pressure between bearing surfaces 32, 44 of a drill bit 10. The method includes constructing a structure 60 which supports the first bearing surface 32 in contact with the second bearing surface 44, and reducing contact pressure between the first and second bearing surfaces 32, 44 by relieving strain energy in the structure 60.

Constructing the structure 60 may include forming the structure as part of a cone 12 and/or a journal 20 of the drill bit 10.

The reduced contact pressure may be due to a lack of material supporting the structure 60 when the surfaces 32, 44 contact each other. The lack of material may be disposed adjacent a wall 52 of a seal groove 38. The lack of material may comprise a recess 58, a hole 78 and/or a void 80.

Constructing the structure 60 may include positioning the structure 60 between the lack of material and the first bearing surface 32.

The reduced contact pressure may be due to a reduced stiffness structure 82 and/or a reduced elastic modulus material 84 of the structure 60. The structure 60 may comprise a functionally gradient material 92, a graduated elastic modulus material 84 and/or may comprise nano structures 76 therein. The structure 60 may comprise a first material 160 having a reduced stiffness relative to a second material 162 which supports the first bearing surface 32 in contact with the second bearing surface 44.

Also described by the above disclosure is a drill bit 10 which includes a first bearing surface 32 in contact with a second bearing surface 44. There is a transition between contact between the first and second bearing surfaces 32, 44, and lack of contact between the first and second bearing surfaces. A structure 60 which supports one of the bearing surfaces 32, 44 has a reduced stiffness. In this manner, a contact pressure between the first and second bearing surfaces 32, 44 is reduced at the transition.

The transition may be at a tangent formed on the first bearing surface 32. The transition may be positioned adjacent a wall 52 of a seal groove 38.

The reduced stiffness of the structure 60 may be due to a lack of material supporting the structure 60. The lack of material may be disposed adjacent a wall 52 of a seal groove 38. The lack of material may comprise a recess 58, a hole 78 and/or a void 80.

The reduced stiffness of the structure 60 may be due to a reduced elastic modulus material 84 of the structure 60.

A deflection of the structure 60 may be increased due to the reduced stiffness of the structure 60 when forces 56 are transmitted between the first and second bearing surfaces 32, 44.

The structure 60 may comprise a first material 160 having a reduced stiffness relative to a second material 162 which supports the one of the first and second bearing surfaces 32, 44.

The above disclosure also describes a drill bit 10 which includes a first bearing surface 32 which contacts a second bearing surface 44, the first bearing surface 32 being formed in a cone 12, the second bearing surface 44 being formed on a journal 20, the cone 12 being rotatably mounted on the journal 20, and there being a transition between contact and lack of contact between the first and second surfaces 32, 44. The cone 12 and/or the journal 20 includes first and second structures 60, 74 which support the first and second bearing surfaces 32, 44 in contact with each other. The first structure 60 has a reduced stiffness relative to a stiffness of the second structure 74.

The reduced stiffness of the first structure 60 may reduce contact pressure between the first and second bearing surfaces 32, 44 at the transition. The transition may be formed at a tangent 54 on the first bearing surface 32.

A deflection of the first structure 60 may be greater than a deflection of the second structure 74 when forces 56 are transmitted between the first and second surfaces 32, 44.

The first structure 60 may comprise a first material 160, and the second structure 74 may comprise a second material 162, and the first material 160 may have a reduced stiffness relative to the second material 162.

A drill bit 10 described by the above disclosure can include a thrust bearing 86 interposed between a cone 12 and a journal 20 of the drill bit 10. A first bearing surface 88 or 90 on the thrust bearing 86 contacts a second bearing surface 40 or 42 on at least one of the cone 12 and the journal 20. There is a transition between contact and lack of contact between the first and second bearing surfaces 88/40 and/or 90/42. A structure 60 supports the first bearing surface 88 or 90, the structure 60 having a reduced stiffness, whereby a contact pressure between the first and second bearing surfaces 88/40 and/or 90/42 is reduced at the transition.

The reduced stiffness of the structure 60 may be due to a lack of material supporting the structure 60. The lack of material may comprise a recess, a hole and/or a void.

The reduced stiffness of the structure 60 may be due to a reduced elastic modulus material 84 of the structure 60.

A deflection of the structure 60 may be increased due to the reduced stiffness when forces 56 are transmitted between the first and second bearing surfaces 88/40 and/or 90/42.

The structure 60 may comprise a functionally gradient material 92. The structure 60 may comprise a graduated elastic modulus material 84. The structure 60 may comprise nano structures 76 therein. The structure 60 may comprise a first material 160 having a reduced stiffness relative to a second material 162 which supports the first bearing surface 32.

It is to be understood that the various examples described above may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present disclosure. The embodiments illustrated in the drawings are depicted and described merely as examples of useful applications of the principles of the disclosure, which are not limited to any specific details of these embodiments.

Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such changes are within the scope of the principles of the present disclosure. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the scope of the present invention being limited solely by the appended claims.

CLAIMS:

1. A drill bit, comprising:

a first bearing surface which contacts a second bearing surface;

a transition between contact and lack of contact between the first and second bearing surfaces; and

a structure which supports one of the first and second bearing surfaces, the structure being part of at least one of a cone and a journal of the drill bit, and the structure having a reduced stiffness, whereby a contact pressure between the first and second bearing surfaces is reduced at the transition due to deflection of the structure.

2 The drill bit of claim 1, wherein the transition is at a tangent formed on the first bearing surface.

3. The drill bit of claim 1, wherein the transition is positioned adjacent a wall of a seal groove.

4. The drill bit of claim 1, wherein the reduced stiffness of the structure is due to a lack of material supporting the structure.

5. The drill bit of claim 4, wherein the lack of material is disposed adjacent a wall of a seal groove.

6. The drill bit of claim 4, wherein the lack of material is selected from one or more of the group consisting of a recess, a hole and a void.

7. The drill bit of claim 1, wherein the reduced stiffness of the structure is due to a reduced elastic modulus material of the structure.

8. The drill bit of claim 1, wherein the deflection of the structure is increased due to the reduced stiffness when forces are transmitted between the first and second bearing surfaces.

9. The drill bit of claim 1, wherein the structure comprises a functionally gradient material.

10. The drill bit of claim 1, wherein the structure comprises a graduated elastic modulus material.

11. The drill bit of claim 1, wherein the structure comprises nano structures therein.

12. The drill bit of claim 1, wherein the structure comprises a first material having a reduced stiffness relative to a second material which supports the one of the first and second bearing surfaces.

13. A drill bit, comprising:

a first bearing surface which contacts a second bearing surface, the first bearing surface being formed in a cone, the second bearing surface being formed on a journal, the cone being rotatably mounted on the journal, and there being a transition between contact and lack of contact between the first and second bearing surfaces; and

at least one of the cone and the journal including first and second structures which support the first and second bearing surfaces in contact with each other, the first structure having a reduced stiffness relative to a stiffness of the second structure.

14. The drill bit of claim 13, wherein the reduced stiffness of the first structure reduces contact pressure between the first and second bearing surfaces at the transition.

15. The drill bit of claim 13, wherein the transition is at a tangent on the first bearing surface.

16. The drill bit of claim 13, wherein the transition is positioned adjacent a wall of a seal groove.

17. The drill bit of claim 13, wherein the reduced stiffness of the first structure is due to a lack of material supporting the first structure.

18. The drill bit of claim 17, wherein the lack of material is disposed adjacent a wall of a seal groove.

19. The drill bit of claim 17, wherein the lack of material is selected from one or more of the group consisting of a recess, a hole and a void.

20. The drill bit of claim 13, wherein the reduced stiffness of the first structure is due to a reduced elastic modulus material of the first structure.

21. The drill bit of claim 13, wherein a deflection of the first structure is greater than a deflection of the second structure when forces are transmitted between the first and second surfaces.

22. The drill bit of claim 13, wherein at least the first structure comprises a functionally gradient material.

23. The drill bit of claim 13, wherein at least the first structure comprises a graduated elastic modulus material.

24. The drill bit of claim 13, wherein at least the first structure comprises nano structures therein.

25. The drill bit of claim 13, wherein the first structure comprises a first material, and the second structure comprises a second material, and wherein the first material has a reduced stiffness relative to the second material.

26. A drill bit, comprising:

a thrust bearing interposed between a cone and a journal of the drill bit;

a first bearing surface on the thrust bearing which contacts a second bearing surface on at least one of the cone and the journal;

a transition between contact and lack of contact between the first and second bearing surfaces; and a structure which supports the first bearing surface, the structure having a reduced stiffness, whereby a contact pressure between the first and second bearing surfaces is reduced at the transition.

27. The drill bit of claim 26, wherein the reduced stiffness of the structure is due to a lack of material supporting the structure.

28. The drill bit of claim 27, wherein the lack of material is selected from one or more of the group consisting of a recess, a hole and a void.

29. The drill bit of claim 26, wherein the reduced stiffness of the structure is due to a reduced elastic modulus material of the structure.

30. The drill bit of claim 26, wherein a deflection of the structure is increased due to the reduced stiffness when forces are transmitted between the first and second bearing surfaces.

31. The drill bit of claim 26, wherein the structure comprises a functionally gradient material.

32. The drill bit of claim 26, wherein the structure comprises a graduated elastic modulus material.

33. The drill bit of claim 26, wherein the structure comprises nano structures therein.

34. The drill bit of claim 26, wherein the structure comprises a first material having a reduced stiffness relative to a second material which supports the first bearing surface.

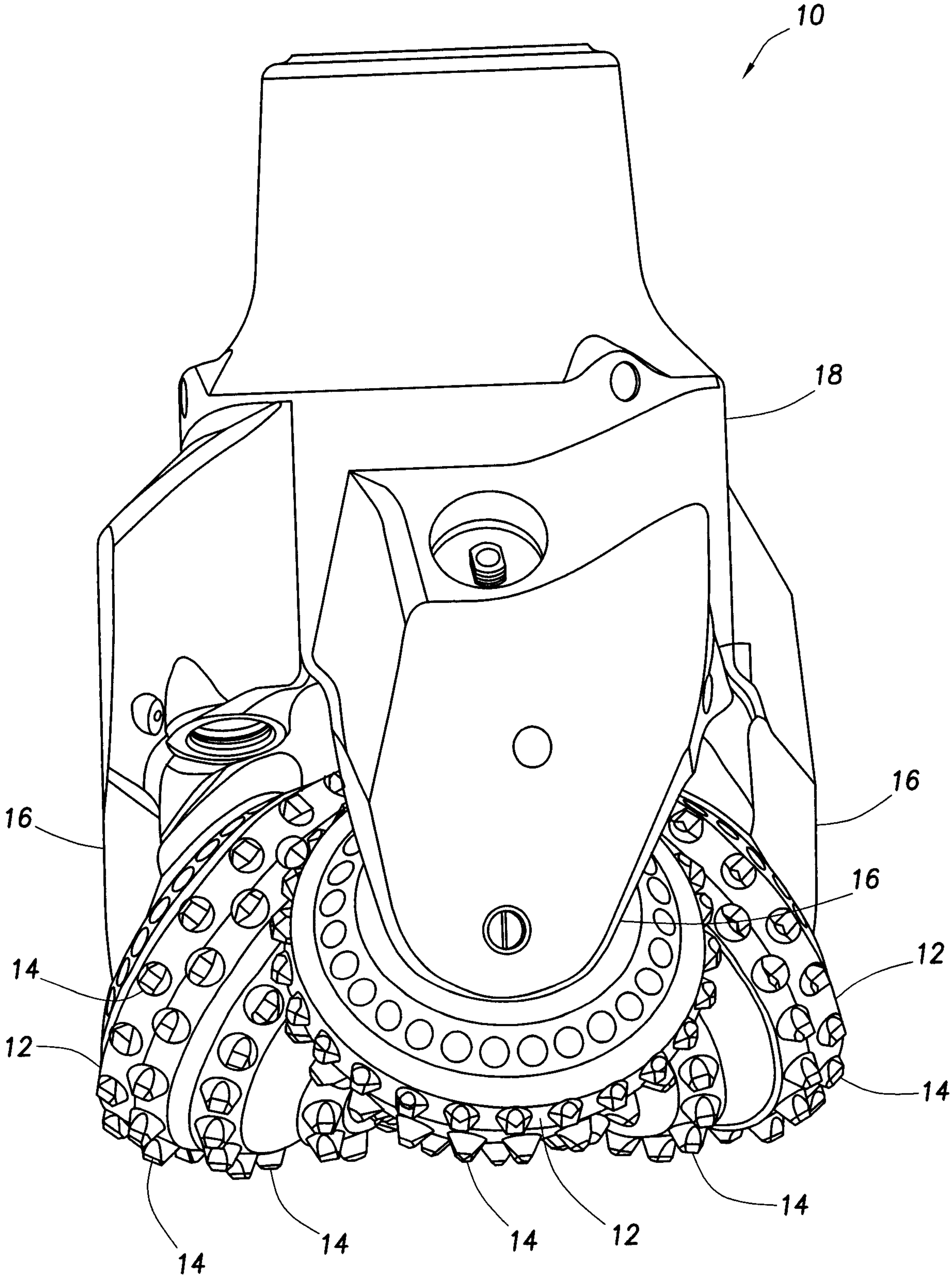


FIG. 1

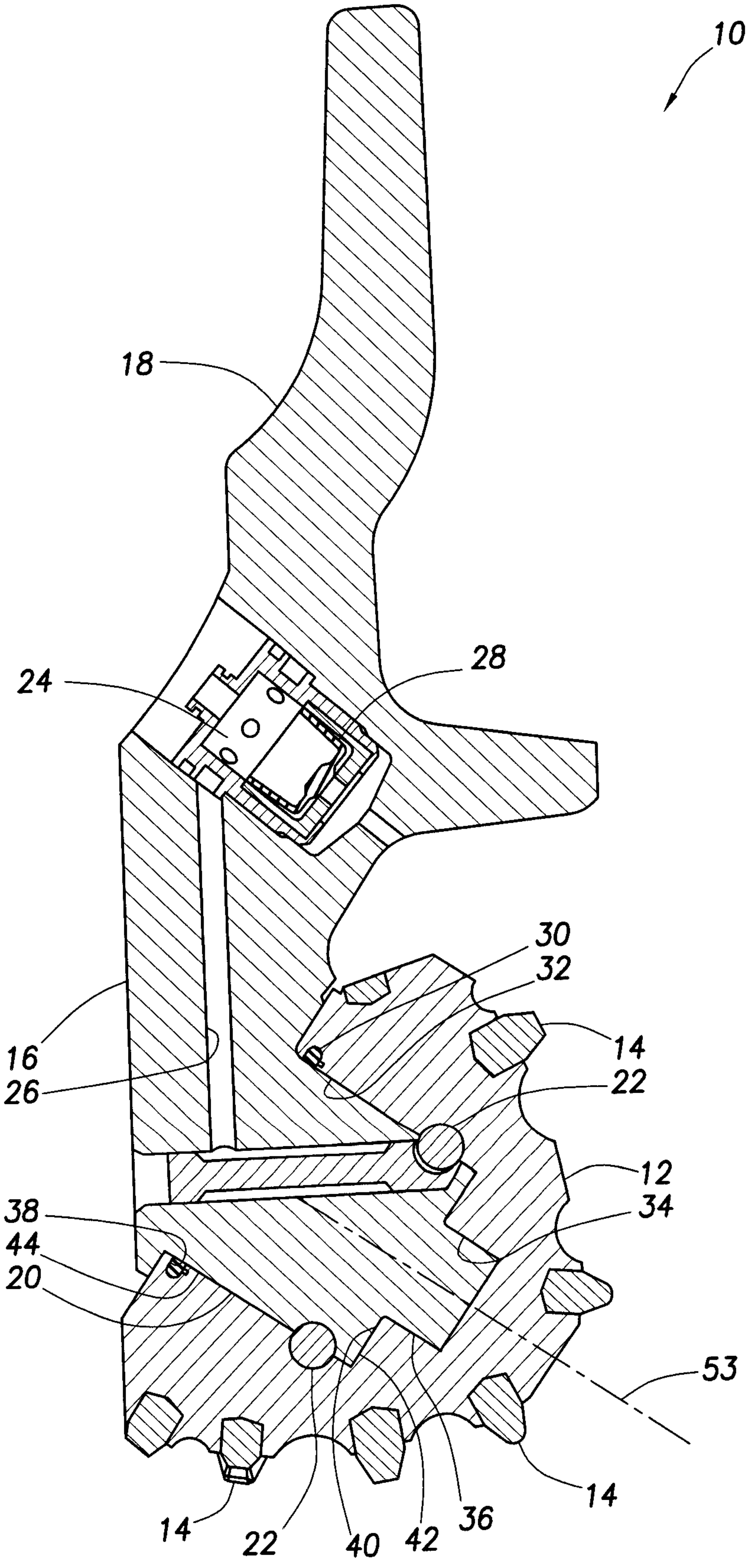


FIG.2

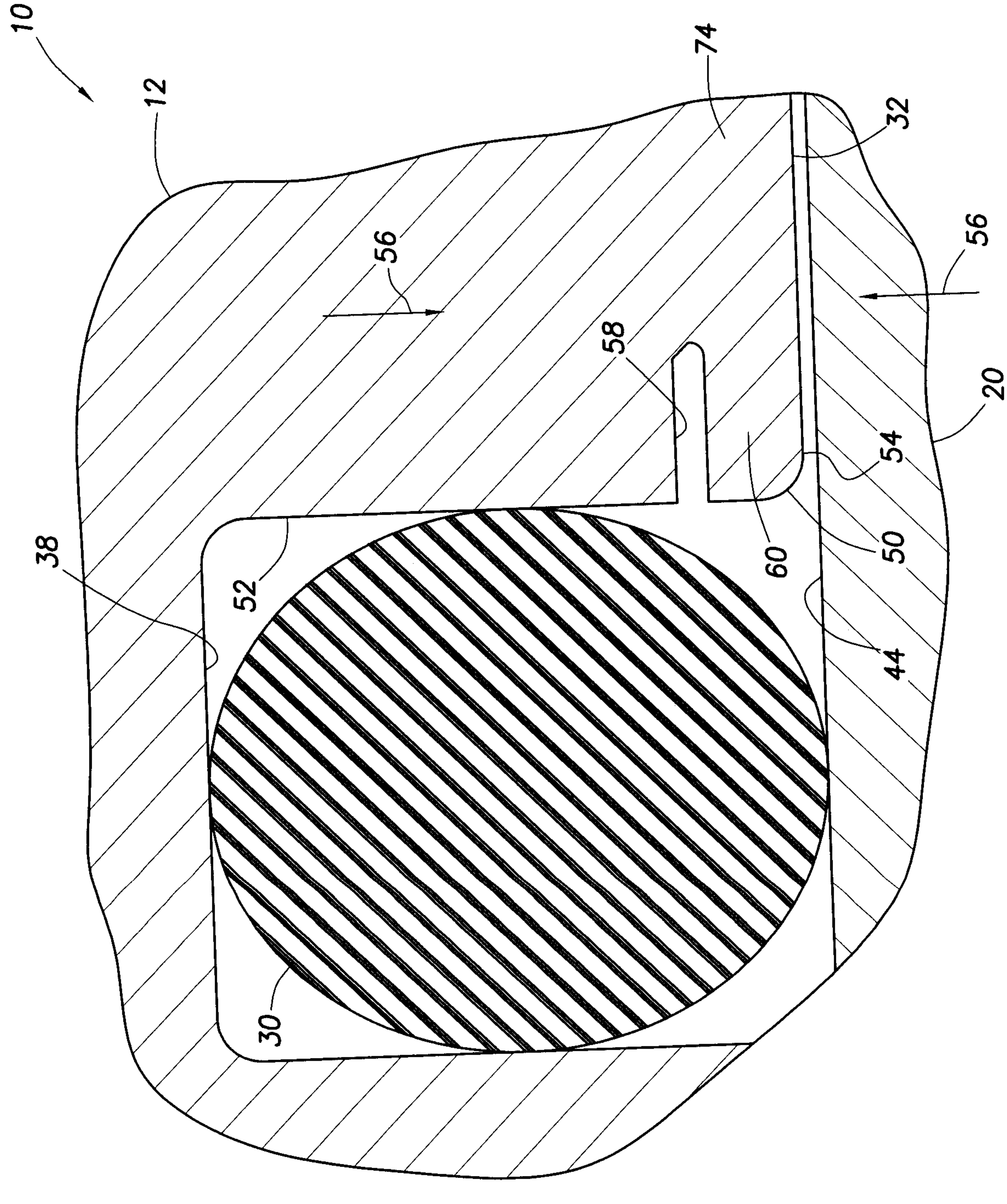


FIG.3

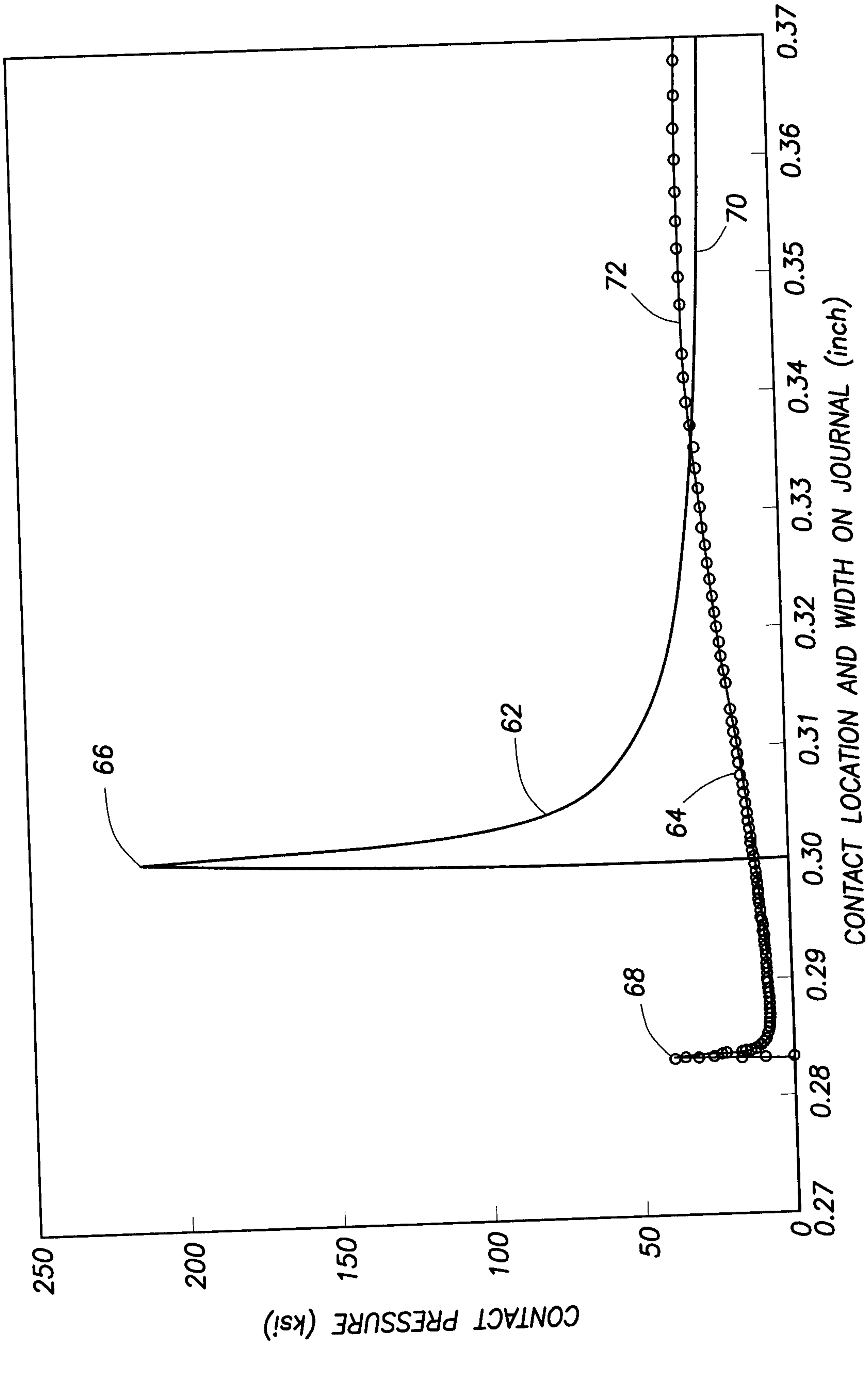

CONTACT PRESSURE (ksi)
0
50
100
150
200
250
CONTACT LOCATION AND WIDTH ON JOURNAL (inch)
0.27
0.28
0.29
0.30
0.31
0.32
0.33
0.34
0.35
0.36
0.37
62
64
66
68
70
72

FIG.4

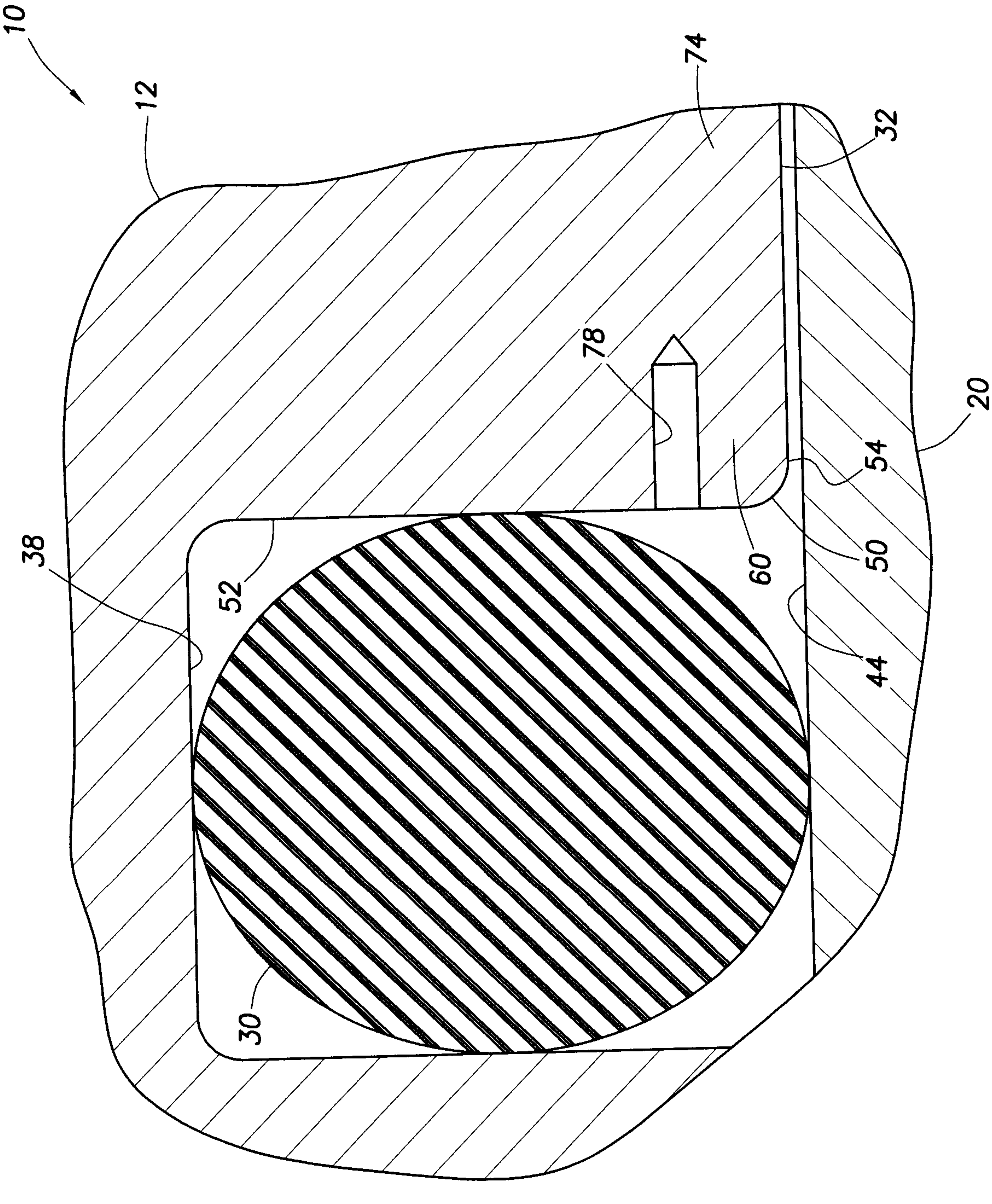


FIG.5

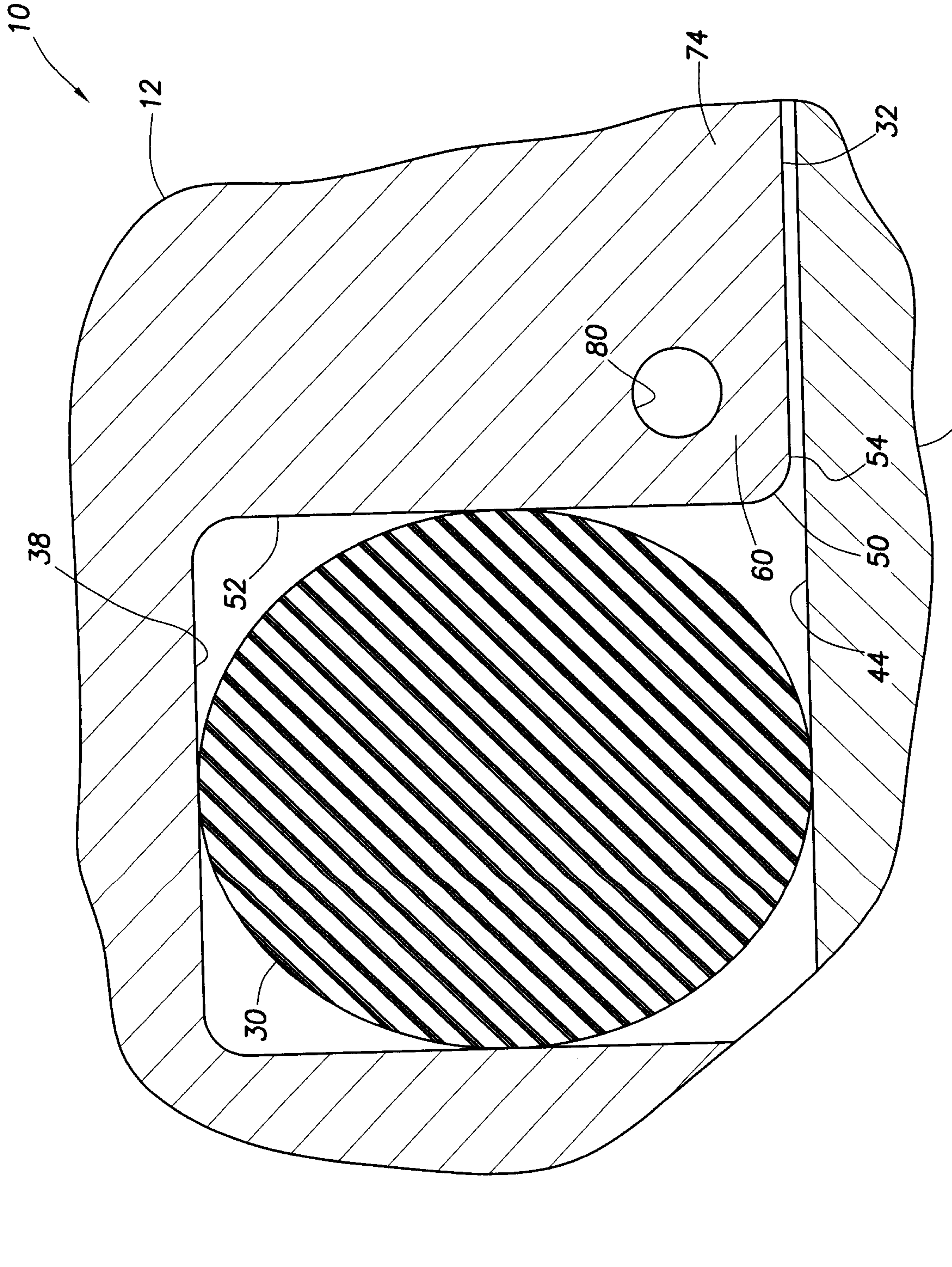
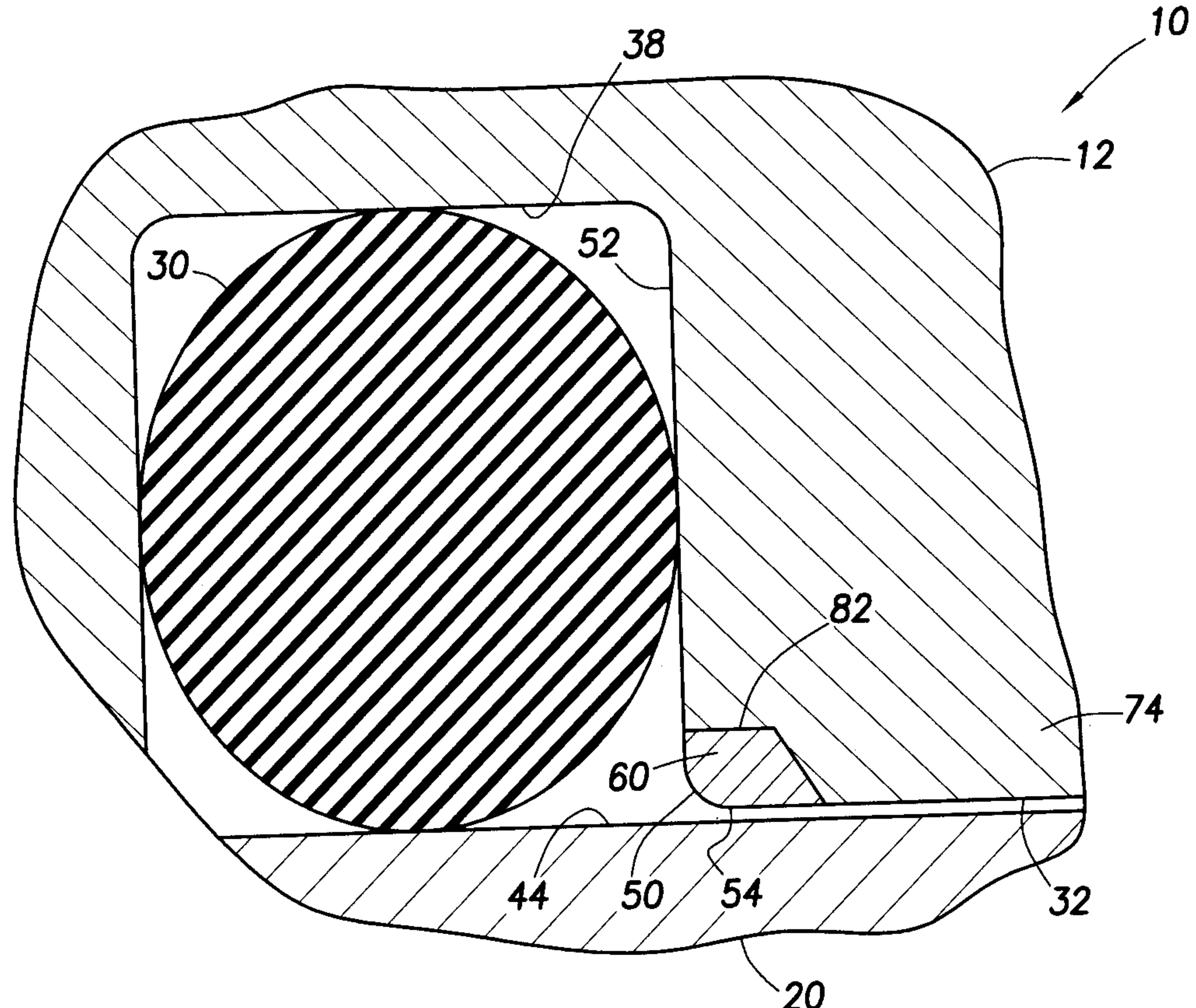


FIG.6


10
38
12
52
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74
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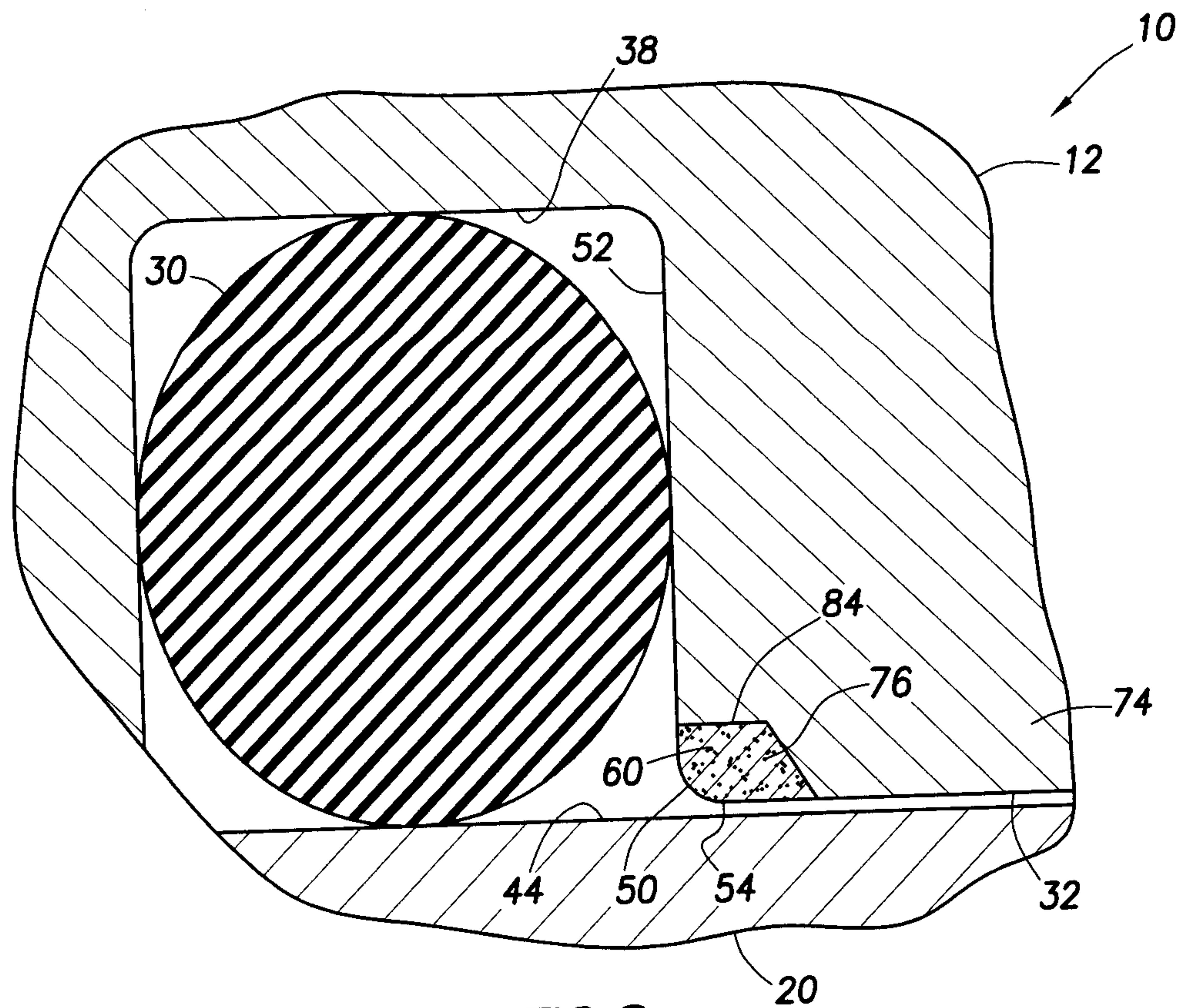
FIG.7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32
20
FIG.8

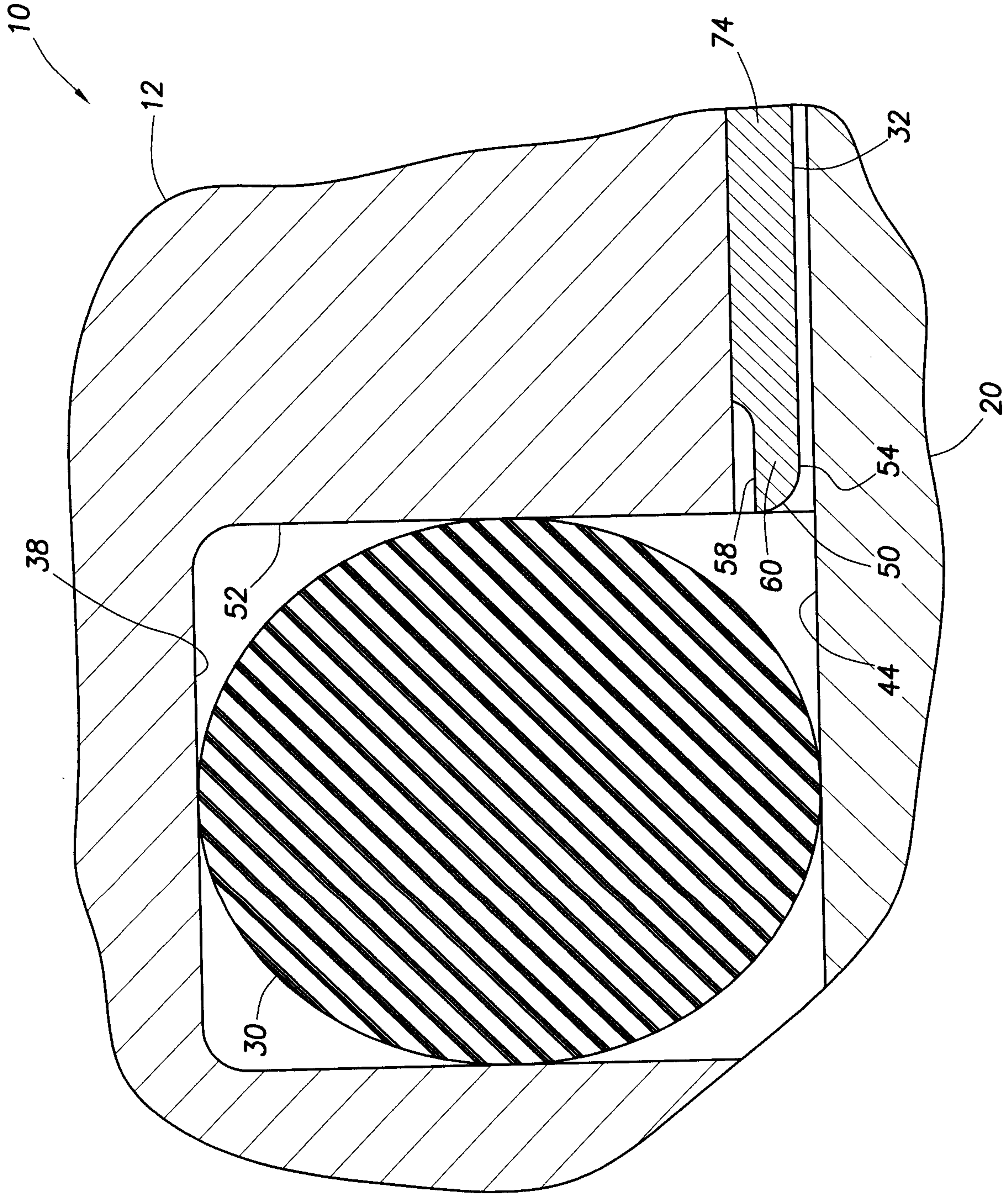
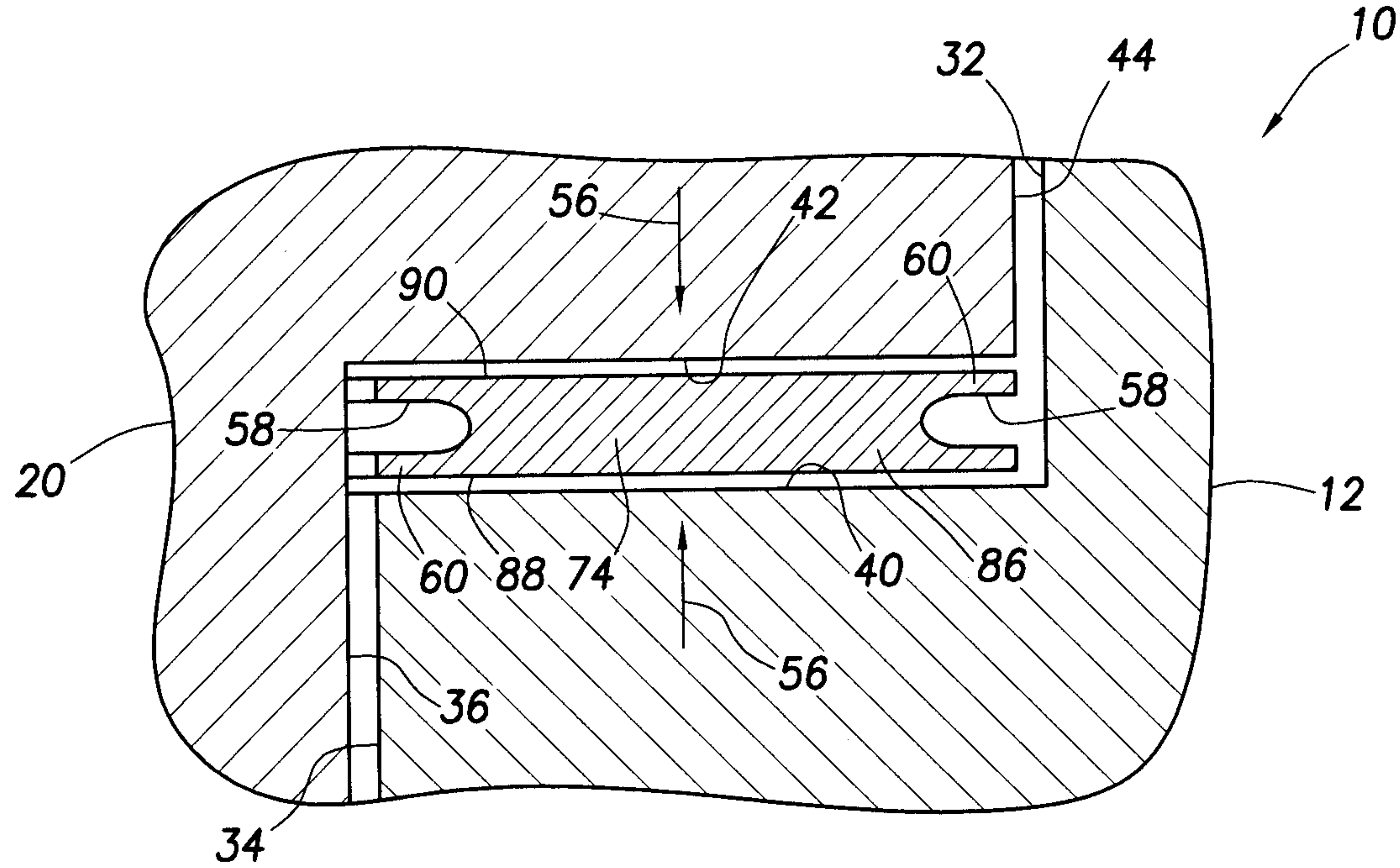


FIG.9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56
42
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58
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12
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88
74
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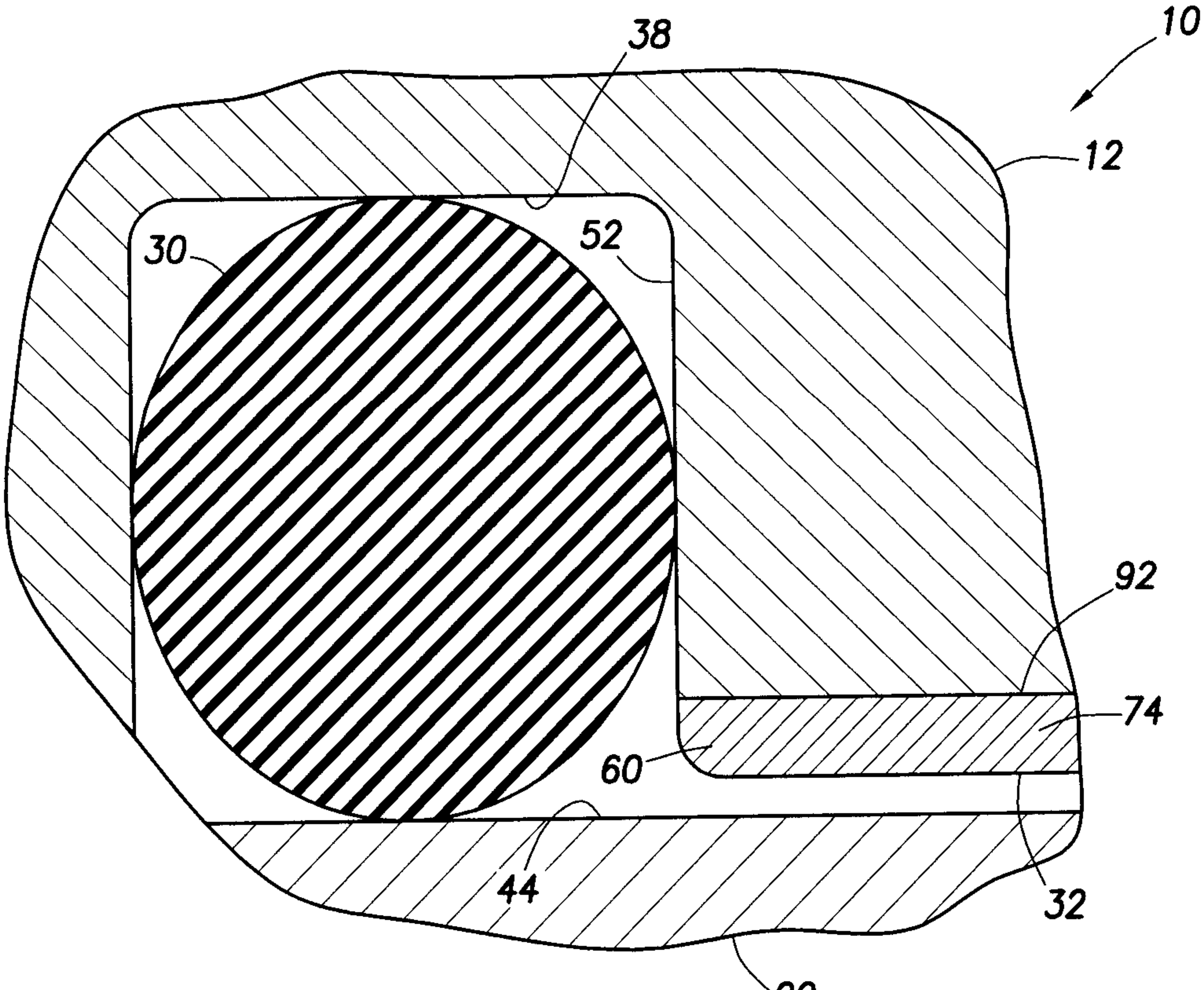
86
56
36
34

FIG.10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92
74
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FIG.11

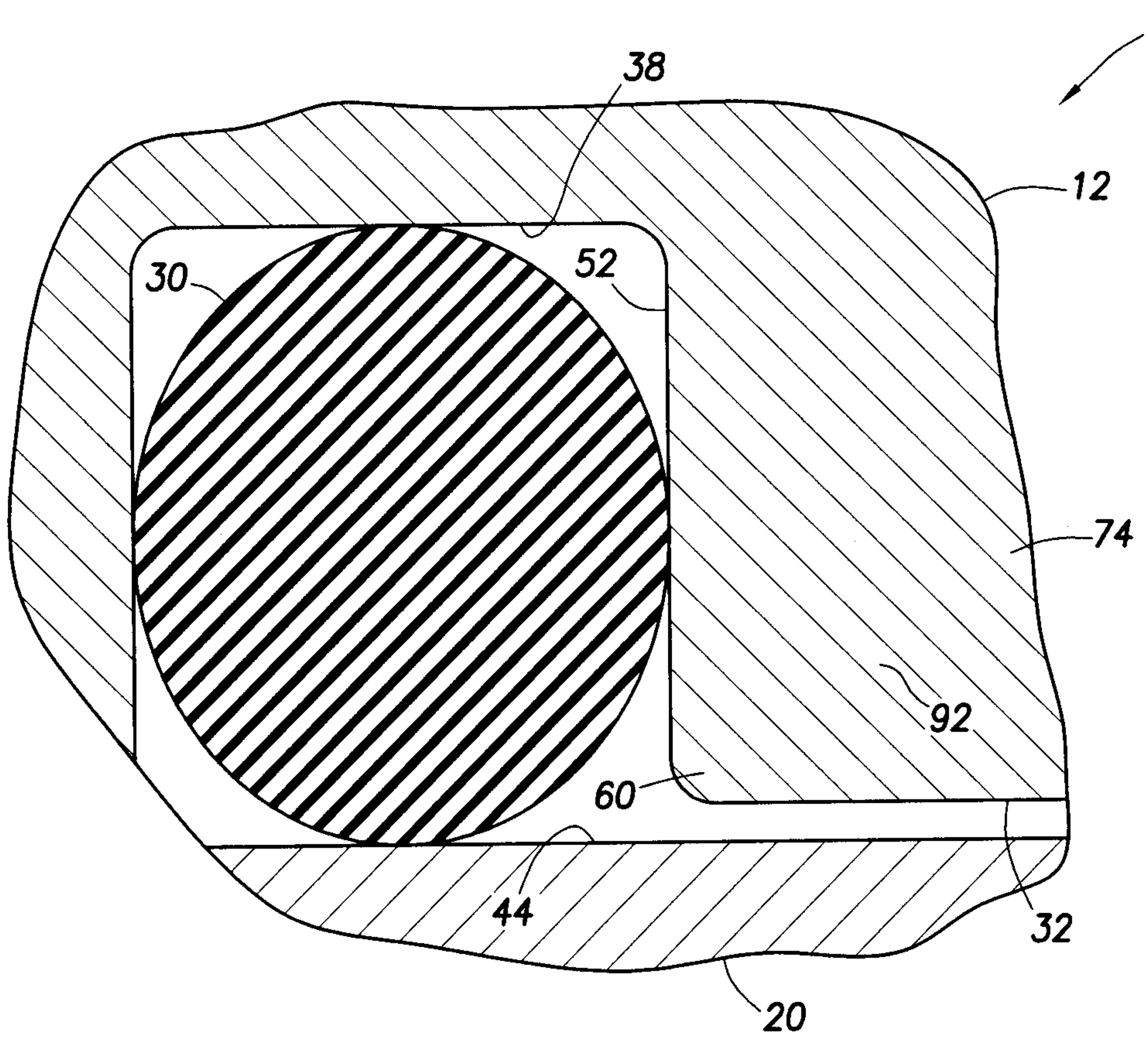


FIG. 12

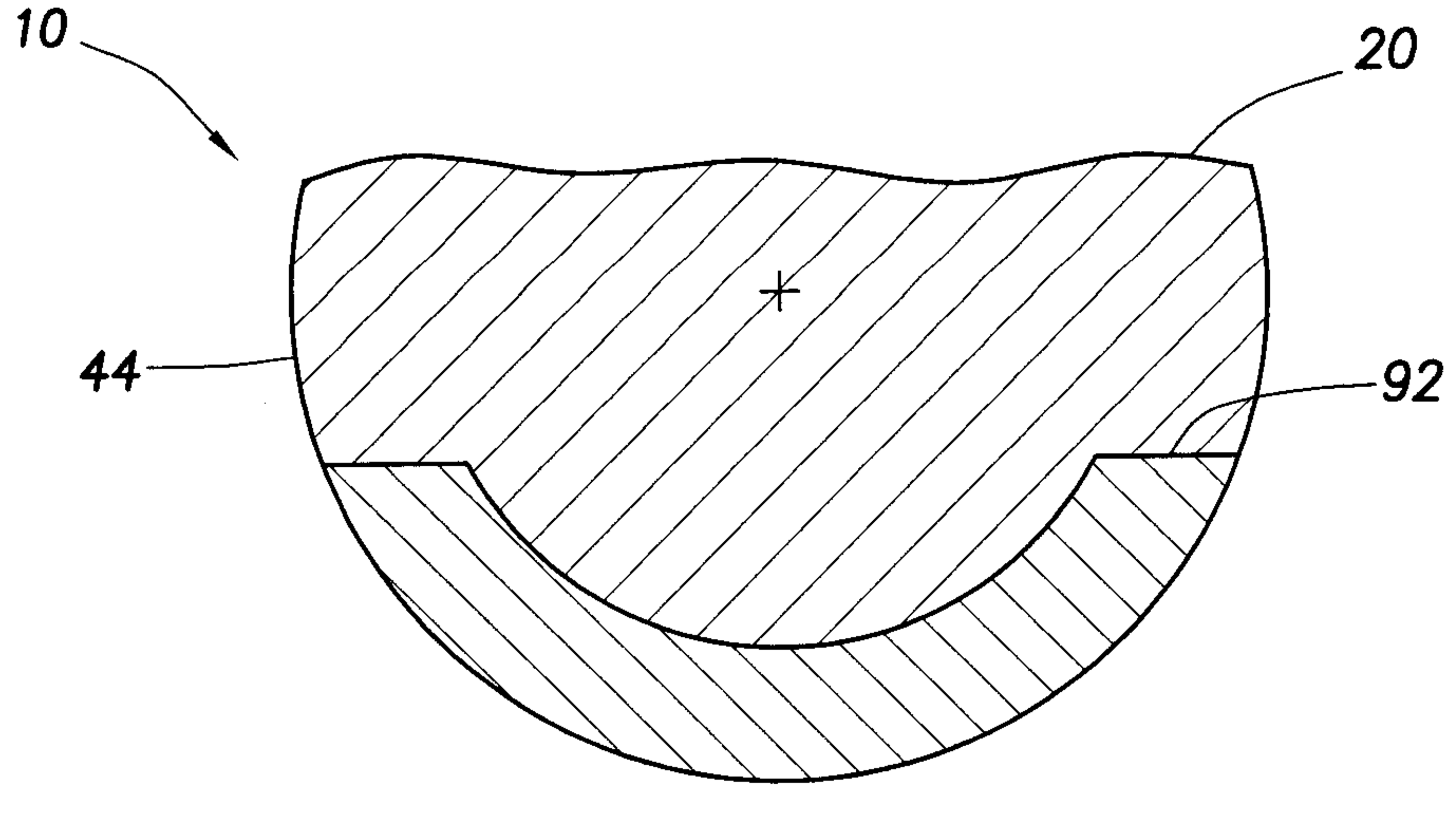


FIG. 13

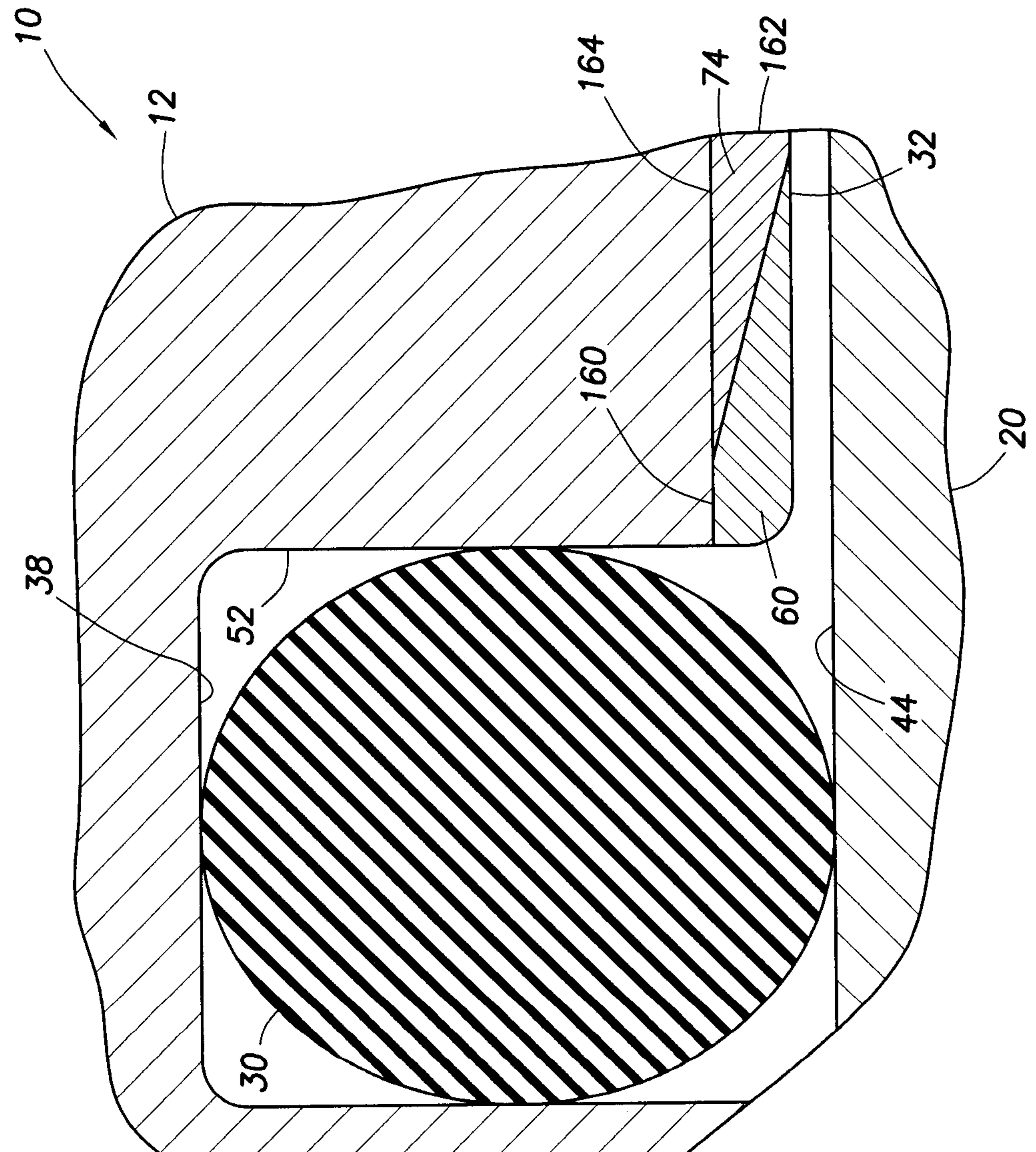
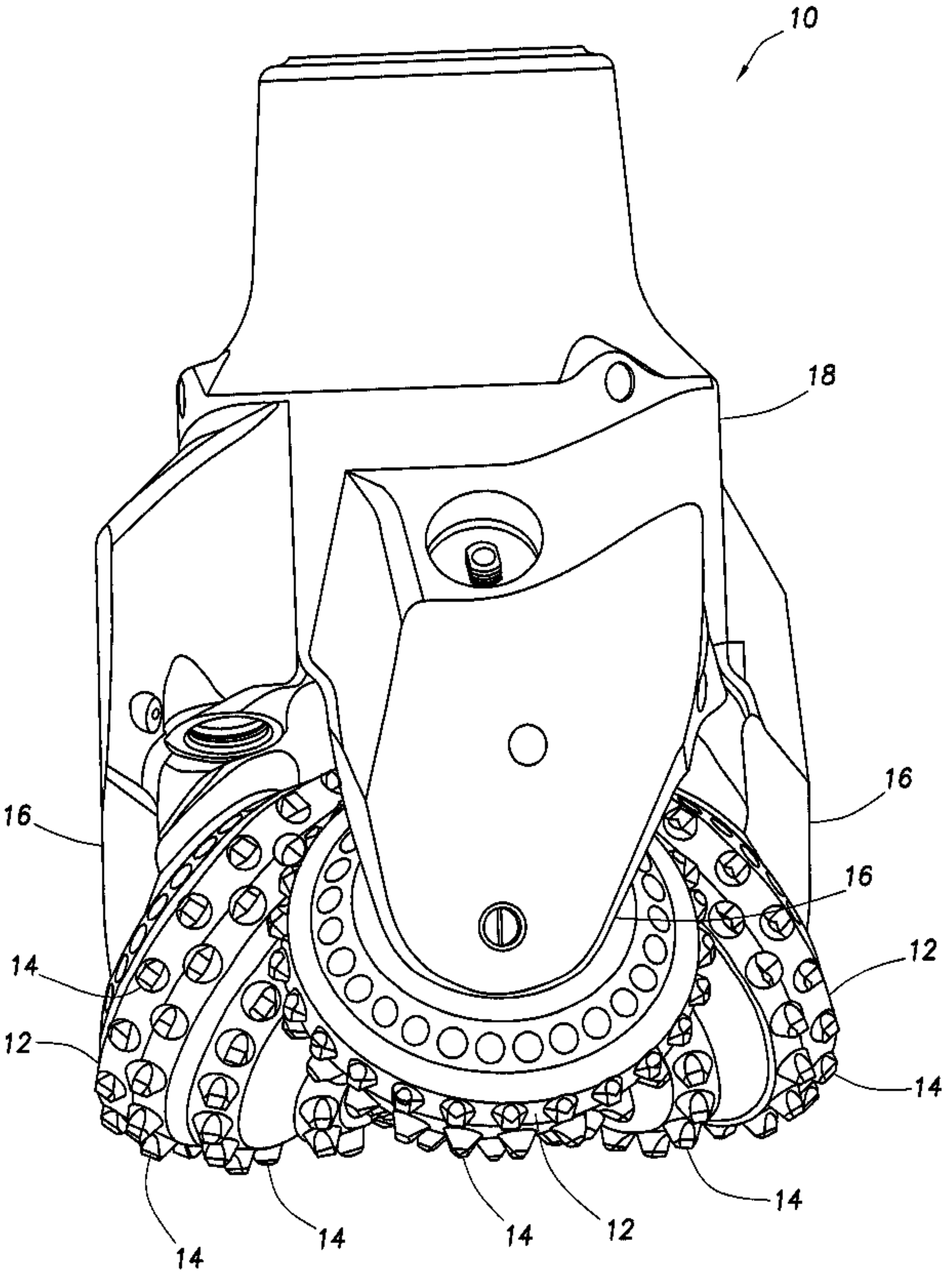


FIG.14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