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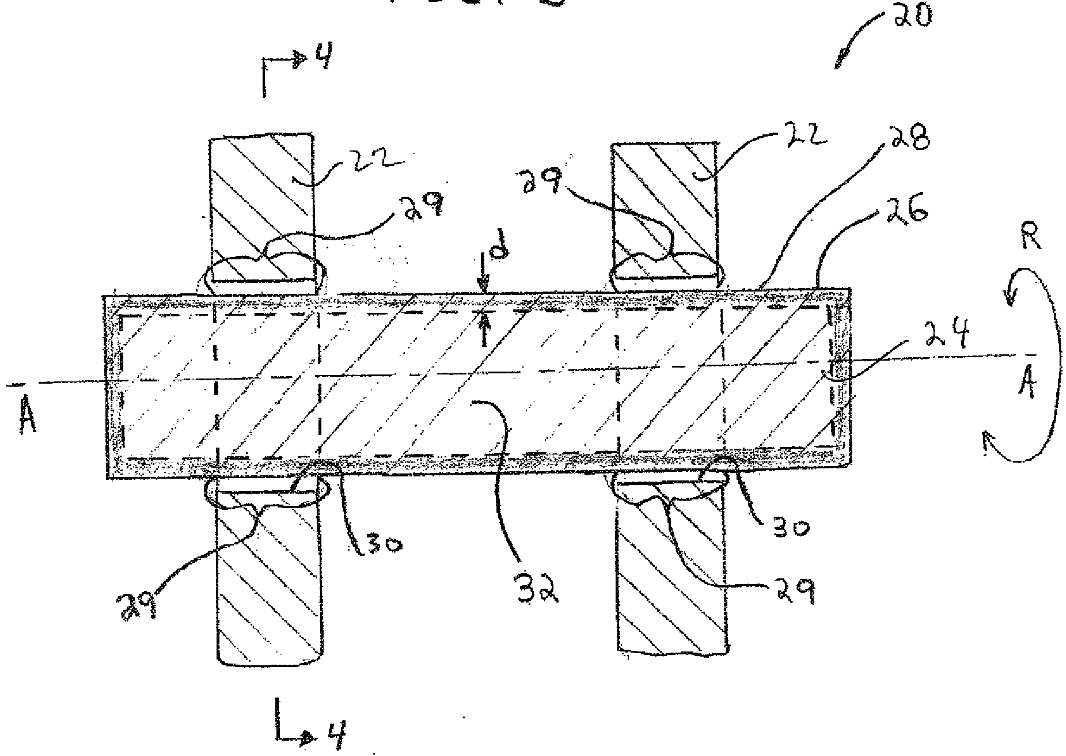
(54) **Surface treated rocker arm shaft**

(57) A shaft (2, 19, 24, 124, 224) for a rocker arm assembly (1, 20, 120, 220) is disclosed. The shaft includes a substantially cylindrical outer surface (26, 126, 226) at least a portion (29, 129, 229) of which defines a bearing surface (28, 128, 228) thereon and an interior core portion (32, 132, 232) located radially inward of the bearing surface. The bearing surface (28, 128, 228) has a hardness greater than that of the core portion (32, 132, 232), for providing wear resistance and deterring crack initiation and propagation.

FIG. 3



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Description

FIELD OF THE INVENTION

[0001] The present invention is generally directed to a surface treated rocker arm shaft for an internal combustion engine and is more specifically directed to a surface hardened rocker arm shaft having a case hardened and/or a highly polished surface that is capable of improved wear resistance and deterrence of crack initiation and propagation.

BACKGROUND OF THE INVENTION

[0002] Internal combustion engines, such as multi-cylinder diesel engines, typically include a crankshaft, a camshaft and a rocker arm shaft. The crankshaft is connected with a plurality of piston rods, which in turn are connected with a plurality of corresponding pistons. Reciprocating movement of the pistons within corresponding combustion cylinders causes rotation of the crankshaft. The crankshaft is typically interconnected with the camshaft via a gear set and thereby rotatably drives the camshaft during operation. The camshaft includes a plurality of cams, with each cam being associated with an inlet valve, and an exhaust valve or a fuel injector valve. More particularly, the rocker arm shaft carries a plurality of rocker arms, with each rocker arm having a roller follower that engages a corresponding cam on the camshaft. Rotation of the camshaft causes oscillatory pivotal movement of the rocker arms around the rocker arm shaft. The rocker arm shaft is subject to cyclic bending moments as a result of forces applied thereto by the roller follower and cam.

[0003] Typically, rocker arm shafts are manufactured from a high strength through hardened steel such as AISI E52100. Through hardening of the steel imparts a high hardness throughout the entire shaft. The expense of some through hardened steels make them impractical for use as rocker arm shafts in typical internal combustion engine.

[0004] In addition, the above mentioned cyclic bending moments can cause fatigue failure of the rocker arm shaft. Although the use of the through hardened steel can improve wear resistance, fatigue generated surface cracks can propagate inwardly through the core portion. Such propagation of the cracks through the core portion has resulted in catastrophic failure of the rocker arm shaft.

SUMMARY OF THE INVENTION

[0005] According to one aspect of the present invention, a shaft for a rocker arm assembly for an internal combustion engine includes a substantially cylindrical outer surface at least a portion of which defines a bearing surface thereon and an interior core portion located radially inward of the outer surface. At least a portion of the outer surface has a hardness greater than that of the core portion, for providing wear resistance and deterring crack initiation and propagation.

[0006] Rocker arm shafts having a bearing surface that has a hardness greater than that of the core portion can improve resistance to the initiation and propagation of surface cracks inwardly through the core portion.

[0007] In one aspect of the present invention, the bearing surface has a Rockwell C scale hardness of at least 59. In another aspect of the present invention, the bearing surface, has a concentration of carbon and/or nitrogen at the outer surface. This concentration extends radially inward from the outer surface to a depth of about 0.063 inches.

[0008] In yet another aspect of the present invention, the bearing surface has an arithmetic mean roughness of less than about 2.5 micro inches.

DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a perspective view of a rocker arm assembly.

[0010] FIG. 2 is a schematic cross sectional view of a valve actuating device and rocker arm assembly.

[0011] FIG. 3 is a schematic cross sectional view of a rocker arm assembly.

[0012] FIG. 4 is a side cross sectional view of the rocker arm assembly of FIG. 3.

[0013] FIG. 5 illustrates the rocker arm assembly of FIG. 3 with a portion of the shaft masked.

[0014] FIG. 6 illustrates a schematic cross sectional view of the rocker arm assembly having a bearing surface having an outer surface treated with a surface finishing process.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] FIG. 1 illustrates a rocker arm assembly generally designated by element number 1. The rocker arm assembly 1 includes a hollow shaft 2 having a longitudinal axis A and four rocker arms 4 rotationally secured thereto. The rocker arms 4 rotationally and cyclically pivot with respect to the rocker arm shaft 2 about the longitudinal axis A as indicated by arrows marked P.

[0016] Referring to FIG. 2, a valve actuating device for an internal combustion engine is generally referred to as numeral 6. The valve actuating device 6 includes an intake valve 8 for selectively opening and closing an intake port 10 of a combustion chamber 12 defined in a cylinder head 14 of an internal combustion engine. In addition, a camshaft 16 includes an intake valve drive cam 18 for actuating the intake valve 8 and a pair of rocker arms 17A and 17B for jointly transmitting the lift of the intake valve drive cam 18 to the intake valve 8. The rocker arm 17A is shown rotatably mounted on a solid cylindrical rocker arm shaft 19.

[0017] FIGS. 3-4 illustrate a portion of a rocker arm assembly 20 for use in overhead valve cylinder deactivation valve trains forming part of an internal combustion engine. The rocker arm assembly 20 includes two rocker arms 22 rotatably mounted on a solid, substantially cylindrical, rocker arm shaft 24 having a longitudinal axis A. During operation, the rocker arms 22 cyclically pivot as illustrated by the arrow R about the axis A. The rocker arm shaft 24 includes an outer surface 26 at least a portion of which defines a bearing surface 28 thereon. Each of the rocker arms 22 includes a substantially cylindrical inside wall 30 defining a bore extending therethrough. The inside wall 30 rotatably engages a contact portion 29 of the bearing surface 28. The rocker arm shaft 24 is shown having a core portion 32 defined by the outer surface 26 and located radially inward of the bearing surface 28. The bearing surface 28 has a surface hardness greater than that of the core portion 32, for improved wear resistance and deterrence of crack initiation and propagation.

[0018] In one embodiment, the rocker arm shaft 24 is manufactured from through hardened ASM 52100 steel and is further case hardened by carburization for increased wear resistance and deterrence of crack initiation and propagation. The carburization case hardening process includes one of gas diffusion, pack diffusion and liquid diffusion. In the carburization process the rocker arm shaft 24, in particular the bearing surface 28 is exposed to a carbon rich atmosphere (e.g., carbon monoxide, carbon powder, or a molten carbon rich bath) for a predetermined period of time. During carburization the carbon rich atmosphere is at a temperature between approximately 1550 °F to 1750 °F. The temperature and time are selected based on a desired surface hardness and penetration depth of the carbon. After carburization, the rocker arm shaft 24 is cooled to a temperature of approximately 70 °F to achieve a desired surface hardness. Cooling can be accomplished by quenching in a liquid and/or by air cooling. The carburization process causes the bearing surface 28 to have a Rockwell hardness, C scale, of at least 59.

[0019] As illustrated in FIGS. 3-4 the carburization process causes the bearing surface 28 and a portion of the shaft 24 radially inward therefrom to an effective case depth d, to have a carbon concentration greater than that of the core 32. The effective case depth d is a distance from a case hardened exterior surface to a furthest point, interior to the case hardened exterior surface, at which the Rockwell hardness, C scale, is about 50. The effective case depth d is measured perpendicular to the bearing surface. In one embodiment, the case depth d is about 0.063 inch (1.6002 mm).

[0020] While the carburization process is described for hardening the bearing surface 28, the present invention is not limited in this regard as the present invention is adaptable to other hardening processes including, but not limited to, nitriding wherein nitrogen is diffused into the bearing surface, carbonitriding wherein carbon and nitrogen are diffused into the bearing surface, flame hardening, induction hardening, laser beam hardening and electron beam hardening.

[0021] In addition, other surface treatment processes to provide wear and impact resistance and deter crack initiation and propagation can be used. Such a surface treatment process includes lapping-like scratching of the surface under extremely high compression of the surface to reduce slip planes, increase surface hardness, increase impact resistance, and increase surface compressive stresses by about twenty percent to a depth of about 0.012 inches. Surface roughness is reduced to less than 1 micro inch. For example, Mikronite Technologies, Inc. of Eatontown, New Jersey has a Mikronite® brand surface treatment processes which can be employed.

[0022] Another process that can deter crack initiation and propagation and increase impact, wear and corrosion resistance is a process using abrasive or non-abrasive media with or without chemical solutions, applied by vibratory methods. Such a process can provide: 1) a superfinished surface, defined as having an ISO Standard No. 4287 Arithmetic Mean Roughness of less than or equal to 2.5 micro inches; 2) an isotropic surface, defined as a surface having no orientation to its surface irregularities; and 3) a specular brightness, defined as a surface in which a clear reflection of an object can be seen. For example, REM Chemicals, Inc. of Southington, Connecticut has an Isotropic Superfinish (ISF®) process that can be employed.

[0023] In one embodiment, the case hardened bearing surface 28 of FIG. 4 is treated with the Mikronite® and/or ISF® processes, either before or after carburization case hardening, such that the bearing surface 28 has an Arithmetic Mean Roughness of less than or equal to 2.5 micro inches, a specular brightness and/or is isotropic.

[0024] The rocker arm assembly of FIG. 5 is similar to that illustrated in FIGS. 3-4. Therefore, like elements will be given like numbers preceded by the numeral 1. FIG. 5 illustrates a rocker arm assembly 120, including two rocker arms 122 rotatably mounted on a solid, substantially cylindrical, rocker arm shaft 124 having a longitudinal axis 1A. The rocker arm shaft 124 includes an outer surface 126 at least a portion of which defines a bearing surface 128 on portions thereof as described below. Each of the rocker arms 122 includes a substantially cylindrical inside wall 130 defining a bore extending therethrough. The inside wall 130 rotatably engages the bearing surface 128 in the contact region 129. The rocker arm shaft 124 is shown having a core portion 132 defined by the outer surface and located radially inward of the bearing surface 128. The contact region 129 of the bearing surface 128 is case hardened by carburization to attain a surface hardness greater than that of the core portion 132, for example a Rockwell hardness, C scale, of at least 59. In addition, portions of the outer surface 126 beyond the contact region 129 are not case hardened and have a hardness about equal to that of the core portion 132. The effective case depth 1d of the case hardened surface of the contact region 129 is about 0.063

inch (1.6002 mm).

[0025] Portions of the outer surface 126 which do not require hardening are coated with a mask 134 prior to initiation of the case hardening process. The mask 134 is made up of a substance impermeable to carbon, for example copper, to preclude diffusion of carbon into the portions of the outer surface 126 which do not require hardening. In one embodiment, the mask 134 is deposited on the portions of the outer surface 126 which do not require hardening by an electro-chemical plating process. After case hardening, for example, carburizing, the mask 134 is removed. Although the mask 134 is described as being copper, the present invention is not limited in this regard as other coatings are also suitable including but not limited to water soluble coatings.

[0026] In another embodiment, the portions of the outer surface 126 in the contact region 129, illustrated in FIG. 5, which are selectively case hardened and/or the portions of the outer surface 126 which do not require hardening, are treated with the Mikronite® and/or ISF® processes either before or after case hardening, such that the bearing surface 128 and/or outer surface 126 has an Arithmetic Mean Roughness of less than or equal to 2.5 micro inches, a specular brightness and/or is isotropic. In one embodiment, a mask 134, similar to that described above for FIG. 5, can be applied to a portion of the outer surface 126, prior to treatment of the rocker arm shaft 124 with the Mikronite® and/or ISF® processes for selectively surface treating the rocker arm shaft 124. The mask 134 is removed after such treatment.

[0027] The rocker arm assembly of FIG. 6 is similar to that illustrated in FIGS. 3-4. Therefore, like elements will be given like numbers preceded by the numeral 2. FIG. 6 illustrates a rocker arm assembly 220, including two rocker arms 222 rotatably mounted on a solid, substantially cylindrical, rocker arm shaft 224 having a longitudinal axis 2A. The rocker arm shaft 224 includes an outer surface 226 at least a portion of which defines bearing surface 228 thereon. Each of the rocker arms 222 includes a substantially cylindrical inside wall 230 defining a bore extending therethrough which rotatably engages the bearing surface 228 in the contact region 229. The rocker arm shaft 224 is shown having a core portion 232 defined by the outer surface 226 and located radially inward of the bearing surface 228.

[0028] Referring again to FIG. 6, at least a portion of the bearing surface 228 has a ISO Standard No. 4287 Arithmetic Mean Roughness of less than or equal to 2.5 micro inches, providing a fine polished finish for improved wear resistance and for deterring crack initiation and propagation. In one embodiment the Arithmetic Mean Roughness is less than 1 micro inch. In one embodiment, the bearing surface 228 is isotropic having no orientation to its surface irregularities. In one embodiment, the bearing surface 228 has a specular brightness, defined as a surface in which a clear reflection of an object can be seen. In one embodiment, surface compressive stresses are increased by about twenty percent above pretreated conditions. Such increase in the surface compressive stresses is affected to a depth of about 0.012 inches.

[0029] While that above rocker arm shafts 28, 128 and 228 are illustrated as solid substantially cylindrical shafts, the present invention is not limited in this regard as other shaft configurations are adaptable for use in the present invention, including but not limited to case hardening and/or surface treatment of any portion of: hollow rocker arm shafts, rocker arm shafts with grooves for receiving and/or guiding the rocker arms and stepped rocker arm shafts having a plurality of different diameters.

[0030] Although the present invention has been disclosed and described with reference to certain embodiments thereof, it should be noted that other variations and modifications may be made, and it is intended that the following claims cover the variations and modifications within the true scope of the invention.

Claims

1. A shaft (2, 19, 24, 124, 224) for a rocker arm assembly (1, 20, 120, 220), said shaft comprising:

a substantially cylindrical outer surface (26, 126, 226) at least a portion (29, 129, 229) of which defines a bearing surface (28, 128, 228) thereon and an interior core portion (32, 132, 232) located radially inward of said bearing surface;
said bearing surface (28, 128, 228) being configured to rotatably engage a mating surface (30, 130, 230) positioned in a receiving bore of a rocker arm (4, 17A, 22, 122, 222); and
said bearing surface (28, 128, 228) having a hardness greater than that of said core portion (32, 132, 232), for providing wear resistance and deterring crack initiation and propagation.

2. The shaft of claim 1, wherein said bearing surface has a Rockwell C scale hardness of at least 59.

3. The shaft claim 1, wherein a concentration of at least one of carbon and nitrogen at said bearing surface (28, 128, 228) and extending radially inward therefrom to an effective case depth of about 0.063 inches, exceeds the concentration of at least one of said carbon and nitrogen in said core portion (32, 132, 232).

4. The shaft of claim 1, wherein portions of said shaft (124) outside of an area (129) wherein said bearing surface (128) and said mating surface (130) engage one another, are masked prior to surface hardening said shaft to prevent surface hardening of said masked area such that said masked area has a hardness about equal to that of said core portion (132).

5. The shaft of claim 3, wherein said bearing surface

(28, 128, 228) has an arithmetic mean roughness of less than about 2.5 micro inches.

6. The shaft of claim 1, wherein said bearing surface (28, 128, 228) is isotropic.

7. The shaft of claim 1, wherein said bearing surface (28, 128, 228) has a specular brightness.

8. A shaft (2, 19, 24, 124, 224) for a rocker arm assembly (1, 20, 120, 220), said shaft comprising:

a substantially cylindrical outer surface (26, 126, 226) at least a portion (29, 129, 229) of which defines a bearing surface (28, 128, 228) thereon;
at least a portion of said bearing surface (28, 128, 228) having an arithmetic mean roughness of less than about 2.5 micro inches, for providing wear resistance and deterring crack initiation and propagation.

9. The shaft of claim 8, wherein said bearing surface (28, 128, 228) is isotropic.

10. The shaft of claim 8, wherein said bearing surface (28, 128, 228) has a specular brightness.

11. The shaft of claim 8, wherein said outer surface (26, 126, 226) defines an interior core portion (32, 132, 232) located radially inward of said bearing surface (28, 128, 228); and
at least a portion of said bearing surface (28, 128, 228) having a hardness greater than that of said core portion (32, 132, 232), for providing wear resistance and deterring crack initiation and propagation.

12. The shaft of claim 11, wherein said bearing surface has a Rockwell C scale hardness of at least 59.

13. The shaft claim 10, wherein a concentration of at least one of carbon and nitrogen at said bearing surface (28, 128, 228) and extending radially inward therefrom to an effective case depth of about 0.063 inches, exceeds the concentration of at least one of said carbon and nitrogen in said core portion (32, 132, 232).

14. The shaft of claim 8, wherein portions of said shaft (124) are masked prior to treatment of said shaft (124) to prevent said at least a portion of said bearing surface (128) from having an arithmetic mean roughness of less than about 2.5 micro inches.

15. A rocker arm assembly comprising:

a shaft (2, 19, 24, 124, 224) according to any one of claims 1-7, and
a rocker arm (4, 17A, 22, 122, 222) having a receiving bore extending therethrough.

FIG 1

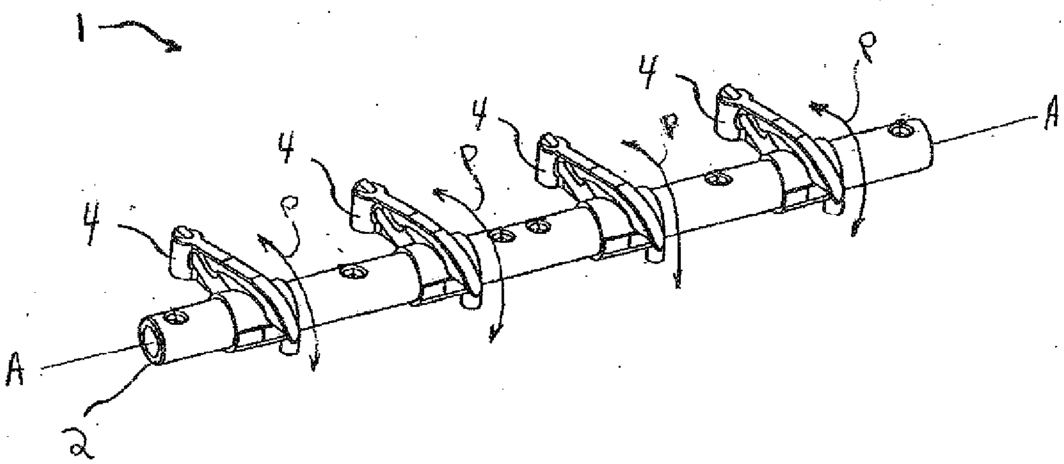


FIG. 2

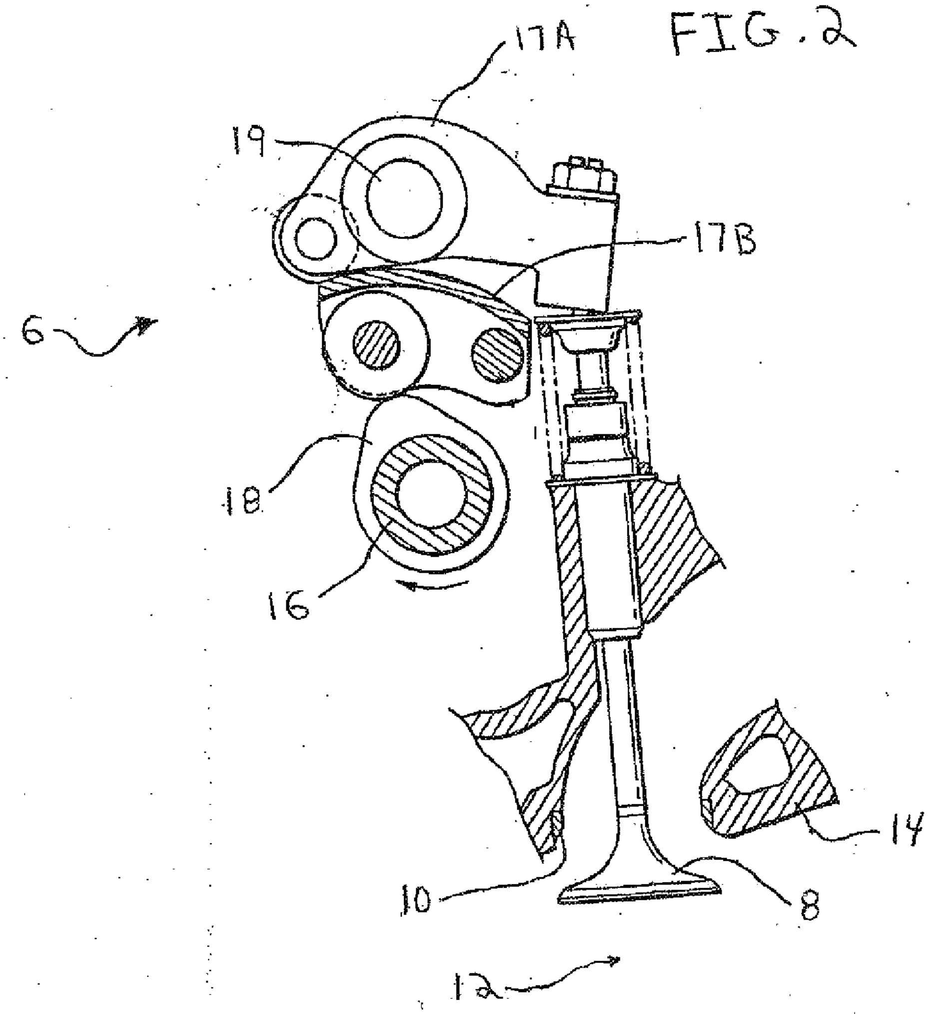


FIG. 3

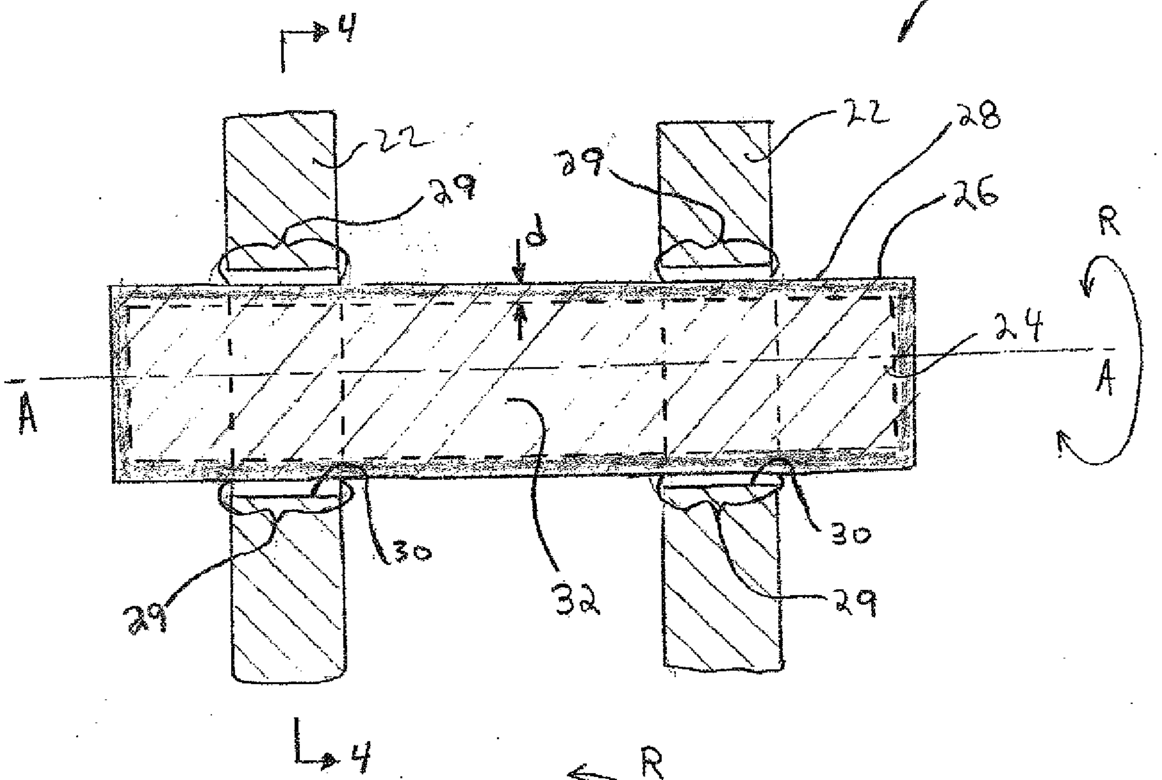


FIG. 4

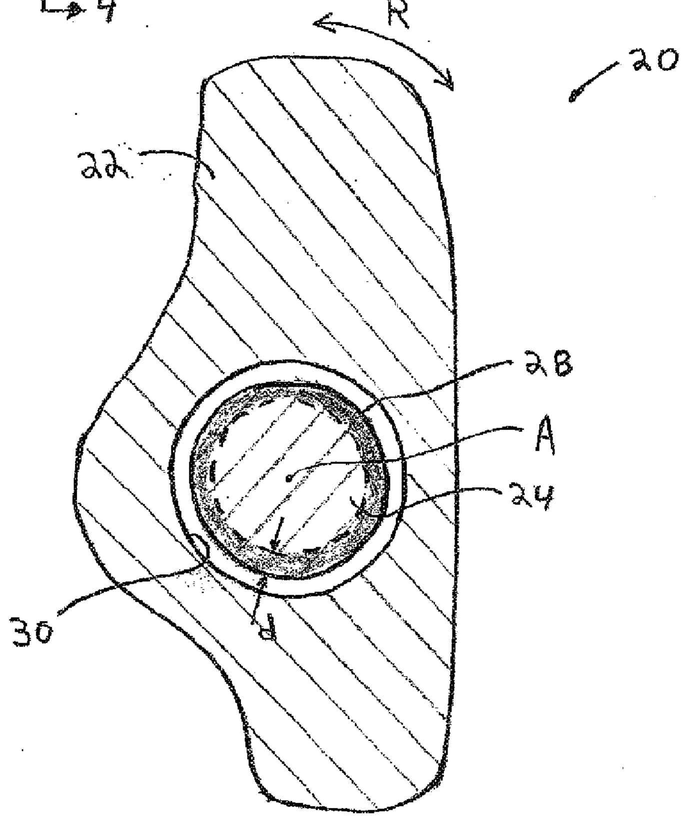
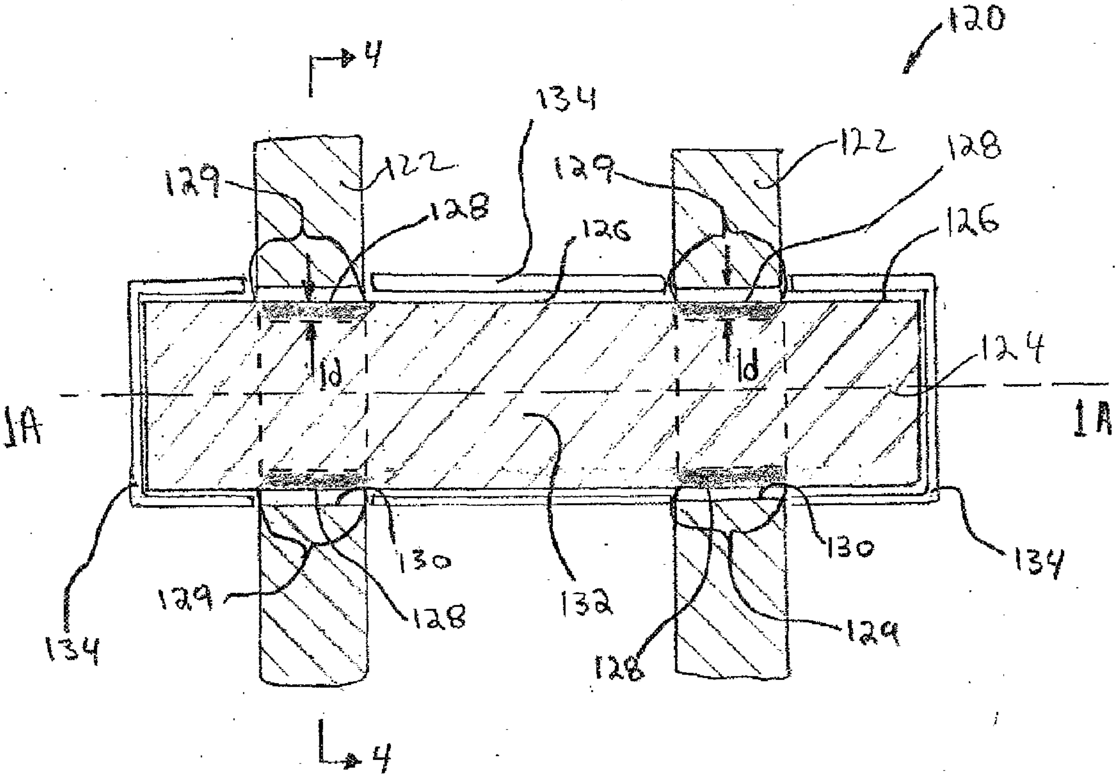


FIG. 5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128
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126
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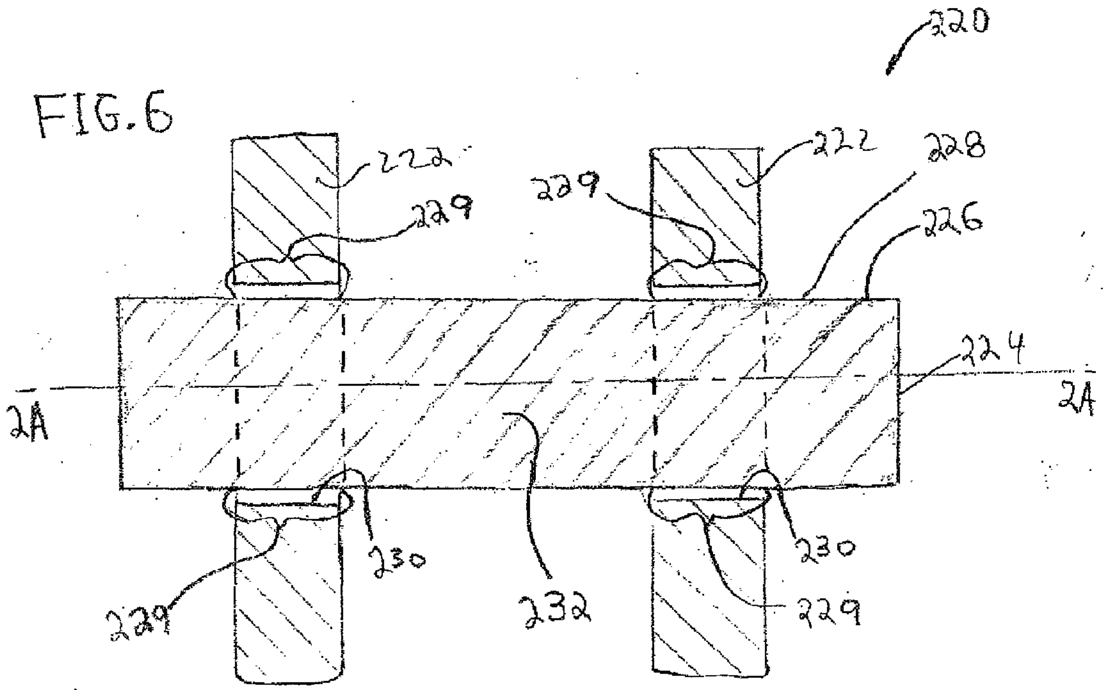
130
4

FIG.6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