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(54) **High pressure fuel pump assembly**

(57) The present invention relates to a high pressure fuel pump assembly (1) for an internal combustion engine. A follower roller (39) is provided for engaging a cam (41) provided on a rotatable driveshaft (43). A shoe (19), which is guided in a shoe guide (21) having a guide face (55), cooperates with the follower roller (39) for reciprocating a fuel pump plunger (3). The shoe (19) has an upper side (25) and a lower side (27); a part cylindrical

recess (37) being formed on the lower side (27) for co-operating with the follower roller (39). At least one aperture (57, 59; 59'; 59", 61; 63) is provided in the shoe guide (21) and/or the shoe (19) to form at least one fluid pathway for maintaining fluid communication between the upper and lower sides (25, 27) of the shoe (19). The present invention also relates to a shoe (19) and a shoe guide (21).

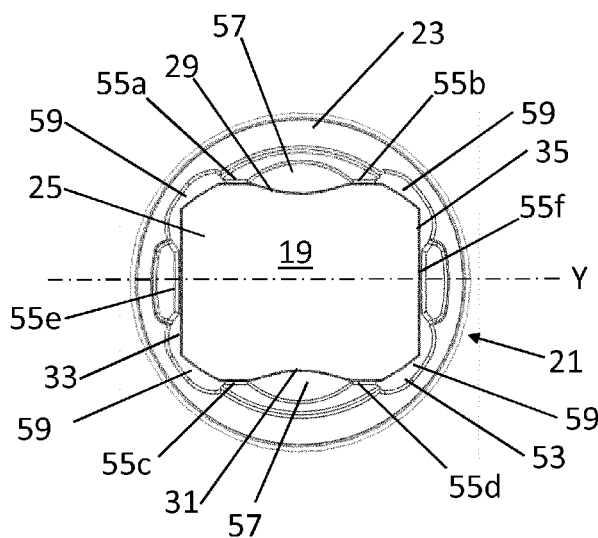


FIG. 2

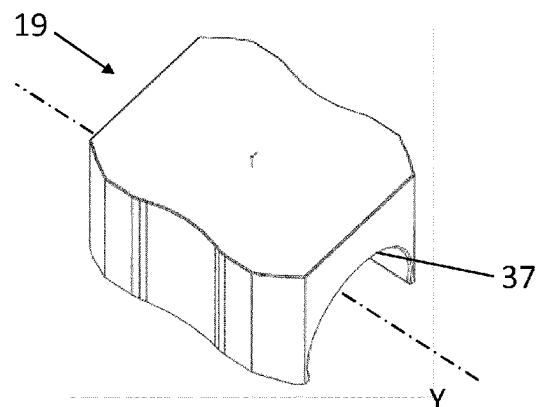


FIG. 3

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Description

TECHNICAL FIELD

[0001] The present invention relates to a high pressure fuel pump for pumping a liquid fuel, such as diesel fuel. The invention also relates to a shoe; and a shoe guide for a high pressure fuel pump.

BACKGROUND OF THE INVENTION

[0002] It has been found that a shoe for engaging a follower roller in a high pressure fuel pump can be subject to fatigue wear. It is desirable to reduce the fatigue wear to extend the service life of the fuel pump.

[0003] It is known from US 7, 568, 461 to modify the end shapes of a follower roller to define two contact areas. This arrangement is intended to permit lubricant to reach the end face surfaces of the follower roller between the contact areas. This arrangement does not address the problem of fatigue wear on the shoe.

[0004] By way of background, a lubricating system for bearing shoes is known from US 4, 209, 079. However, this arrangement is intended for bearing surfaces having a large diameter to support a heavy element such as a drum of a crusher. The arrangement described therein cannot readily be applied to a high pressure fuel pump system

[0005] The present invention sets out to help ameliorate or overcome at least some of the problems associated with prior art systems.

SUMMARY OF THE INVENTION

[0006] Aspects of the present invention relate to a high pressure fuel pump; a shoe; and a shoe guide for a high pressure fuel pump.

[0007] In a further aspect, the present invention relates to a high pressure fuel pump assembly for an internal combustion engine, the pump assembly comprising:

a follower roller engageable with a cam provided on a rotatable driveshaft;
a shoe for reciprocating a fuel pump plunger; and
a shoe guide having a guide face for guiding the shoe;
the shoe having an upper side and a lower side, a part cylindrical recess being formed on the lower side of the shoe for cooperating with the follower roller; wherein at least one aperture is provided in the shoe guide and/or the shoe to form at least one fluid pathway for maintaining fluid communication between the upper and lower sides of the shoe. This arrangement can promote the flow of lubricant within the pump assembly. In particular, said at least one aperture can improve hydrodynamic lubrication at the interface between the shoe and the follower roller. The lubrication between the follower roller and the

cam can also be improved. Moreover, sliding friction can be reduced to increase the fatigue life of the shoe.

[0008] The shoe is typically provided between an upper cambox and a lower cambox. The at least one fluid pathway can be suitable for maintaining fluid communication between an upper cambox and a main cambox of the pump assembly. The circulation of lubricant between the upper cambox and the main cambox can be improved. The at least one aperture can improve pressure stability between the upper cambox and the main cambox.

[0009] The high pressure fuel pump can further comprising a bypass channel arranged to bypass the shoe assembly. The bypass channel can provide an alternate fluid pathway between the upper cambox and the main cambox. The provision of the bypass channel and said at least one fluid pathway can promote the circulation of lubricant within the pump.

[0010] The at least one aperture can extend substantially parallel to a longitudinal axis of the shoe (along which the shoe travels). Alternatively, said at least one aperture could be inclined relative to said longitudinal axis.

[0011] The at least one aperture can comprise a first channel formed in a sidewall of the shoe. The first channel can provide a fluid pathway past the shoe in the pump assembly. The at least one aperture can comprise a concave section formed in a sidewall of the shoe. The concave section can form a fluid pathway between the shoe and the shoe guide. In certain embodiments, the shoe can be elongated in a transverse direction, thereby defining long and short sidewalls. An aperture could be formed in one of the short sidewalls of the shoe. Alternatively, with a view to reducing loading on the shoe, an aperture could be formed in one of the long sidewalls of the shoe.

[0012] The at least one aperture could comprise a second channel formed in the shoe guide. The second channel can provide a fluid pathway past the shoe in the pump assembly. The second channel could be a cut-out formed in the guide face of the shoe guide. The second channel could, for example, comprise a concave section.

[0013] The pump assembly could comprise either said first channel in the shoe or said second channel in the shoe guide. Alternatively, both said first and second channels could be provided. The first and second channels could be aligned with each other to form the fluid pathway. The fluid pathway could, for example, have an elliptical or circular profile.

[0014] The at least one aperture could comprise a bore formed in the shoe and/or the shoe guide. One or more bores could be provided in addition to, or instead of forming an aperture in the shoe and/or the shoe guide. The bore can be coincident with or offset from the part cylindrical recess formed on the lower side of the shoe.

[0015] In a further aspect, the present invention relates

to a shoe for cooperating with a follower roller in a high pressure fuel pump, the shoe having an upper side, a lower side and a sidewall; a part cylindrical recess being formed on the lower side of the shoe for receiving a follower roller; wherein at least one aperture is provided in said shoe for forming at least one fluid pathway to maintain fluid communication between the upper and lower sides of the shoe.

[0016] The at least one aperture can comprise a first channel formed in the sidewall of the shoe. The at least one aperture can comprise a concave section formed in the sidewall of the shoe. In certain embodiments, the shoe can be elongated in a transverse direction, thereby defining two long sidewalls and two short sidewalls. An aperture could be formed in one or both of the short sidewalls of the shoe. Alternatively, with a view to reducing loading on the shoe, an aperture could be formed in one or both of the long sidewalls of the shoe.

[0017] Alternatively, or in addition, the at least one aperture can comprise a bore formed in the shoe. The bore can extend substantially parallel to a longitudinal axis of the shoe. The bore can be coincident with, or offset from the part cylindrical recess formed on the lower side of the shoe.

[0018] In a still further aspect, the present invention relates to a shoe guide for guiding a shoe in a high pressure fuel pump, the shoe guide having an inner wall defining at least one guide face for engaging a sidewall of the shoe; wherein at least one aperture is provided in said inner wall for forming at least one fluid pathway past the shoe. The at least one aperture can comprise a channel or recess formed in the inner wall of the shoe guide.

[0019] The present invention also relates to an assembly comprising a shoe and a shoe guide as described herein.

[0020] The pump assembly and shoe have been described herein using relative positional terms, such as upper and lower. These terms are used with reference to the illustrated pump assembly to assist with the explanation of the present invention and are not intended to be limiting on the scope of protection conferred.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying figures, in which:

Figure 1 shows a cross sectional view of a high pressure fuel pump incorporating a shoe and a shoe guide according to the present invention;

Figure 2 shows a plan view of a shoe and a shoe guide according to a first embodiment of the present invention;

Figure 3 shows a perspective view of the shoe shown in Figure 2;

Figure 4 shows a plan view of a shoe and a shoe guide according to a second embodiment of the

present invention;

Figure 5 shows a perspective view of the shoe shown in Figure 4;

Figure 6 shows a plan view of a shoe and a shoe guide according to a third embodiment of the present invention; and

Figure 7 shows a perspective view of a modified shoe according to the present invention.

DETAILED DESCRIPTION OF AN EMBODIMENT

[0022] A high pressure fuel pump 1 in accordance with the present invention is shown in Figure 1. The fuel pump 1 is intended for pumping diesel fuel to a common rail of an internal combustion engine. It will be appreciated, however, that the techniques described herein could be used in other applications.

[0023] The fuel pump 1 comprises a plunger 3 for supplying high pressure fuel to a fuel injection system. The plunger 3 is located in a housing 5 comprising a hydraulic head 7 having a fuel inlet port 9 and a fuel outlet port 11. An inlet valve 13 is provided in the fuel inlet port 9 and an outlet valve 15 is provided in the fuel outlet port 11. The plunger 3 is movable along a longitudinal axis X in a reciprocating action within a pumping chamber 17.

[0024] A lower end of the plunger 3 is coupled to a shoe 19 movable along the longitudinal axis X. The shoe 19 is supported in a shoe guide 21 formed by a cylindrical insert 23 provided in the housing 5. As shown in Figures 1 and 2, the shoe 19 is elongated along a transverse axis Y and comprises an upper side 25, a lower side 27, a first sidewall 29, a second sidewall 31, a third sidewall 33 and a fourth sidewall 35. The shoe 19 has a generally rectangular plan form and the first and second sidewalls 29, 31 are longer than the third and fourth sidewalls 33, 35. A part cylindrical recess 37 is formed in the lower side 27 of the shoe 19 to receive a follower roller 39.

[0025] The follower roller 39 is movably mounted in the shoe guide 21. Specifically, the follower roller 39 can rotate about the transverse axis Y and translate along the longitudinal axis X. The follower roller 39 is arranged to follow a cam 41 provided on a rotatable driveshaft 43. The rotation of the driveshaft 43 causes the cam 41 to displace the follower roller 39 and the shoe 19 upwardly, thereby advancing the plunger 3 into the pumping chamber 17. A spring 45 is provided to bias the plunger 3 downwardly, thereby retracting the plunger 3 and maintaining the follower roller 39 in contact with a surface of the cam 41. The rotation of the driveshaft 43 causes the plunger 3 to reciprocate within the pumping chamber 17.

[0026] The spring 45 and the lower end of the plunger 3 are provided in an upper cambox 47 within the housing 5. The driveshaft 43 is provided in a main cambox 49 positioned beneath the upper cambox 47. The upper side 25 of the shoe 19 is in fluid communication with the upper cambox 47; and the lower side 27 of the shoe 19 (and the follower roller 39) is in fluid communication with the main cambox 49. A bypass conduit 51 is formed in the

housing 5 to define a fluid channel between the upper cambox 47 and the main cambox 49.

[0027] As shown in Figure 2, an inner wall 53 of the shoe guide 21 is profiled to define a plurality of discrete shoe guide faces 55a-f extending parallel to the longitudinal axis X to contact the sidewalls 29, 31, 33, 35 of the shoe guide 21. The guide faces 55a-f maintain the alignment of the shoe 19 as it travels within the shoe guide 21. In the present embodiment, the lateral guide faces 55a-d engage the first and second sidewalls 29, 31; and the end guide face 55e, f engage the third and fourth sidewalls 33, 35.

[0028] The shoe 19 and the shoe guide 21 are also profiled to define two side channels 57 and four corner channels 59 for maintaining the upper cambox 47 in fluid communication with the main cambox 49. The side channels 57 are defined by concave sections formed in the first and second sidewalls 29, 31 of the shoe 19 and also in the inner wall 53 of the shoe guide 21. Accordingly, the side channels 57 have a generally elliptical cross section. The corner channels 59 are defined by concave cut-outs formed in the inner wall 53 of the shoe guide 21 and by forming each corner of the shoe 19 in a radius. A perspective view of the shoe 19 is shown in Figure 3.

[0029] In use, the driveshaft 43 rotates about an axis parallel to the transverse axis Y. The rotation of the cam 41 displaces the follower roller 39 and the shoe 19 upwardly within the shoe guide 21. The spring 45 biases the shoe 19 and the follower roller 39 downwardly. Since the plunger 3 is coupled to the shoe 19, the plunger 3 advances and retracts in a reciprocating motion within the pumping chamber 17. As the plunger 3 retracts, the outlet valve 15 is closed and fuel is drawn into the pumping chamber 17 through the fuel inlet port 9. When the plunger 3 advances, the inlet valve 13 is closed and the fuel is pressurised in the pumping chamber 17 before exiting through the fuel outlet port 11.

[0030] The bypass channel 51 provides fluid communication between the upper cambox 47 and the main cambox 49. Thus, lubricant can travel from the main cambox 49 to the upper cambox 47 via the bypass conduit 51. The channels 57, 59 formed in the shoe 19 provide additional fluid pathways between the upper cambox 47 and the main cambox 49. The channels 57, 59 can thereby promote the circulation of lubricant within the pump 1. In particular, the channels 57, 59 can improve hydrodynamic lubrication at the interface between the shoe 19 and the follower roller 39; and at the interface between the follower roller 39 and the cam 41. The sliding friction can be reduced, thereby increasing fatigue life and improving overall robustness of the pump 1. The channels 57, 59 may also improve damping, thereby improving pressure stability between the upper cambox 49 and the main cambox 47. There is potentially also a reduction in the turbulence created within the upper cambox 49 and the main cambox 47.

[0031] A shoe and shoe guide according to a second embodiment of the present invention are illustrated in

Figures 4 and 5. The second embodiment is similar to the first embodiment described herein and like reference numerals will be used for like components, albeit suffixed with a prime modifier for clarity.

[0032] The shoe 19' and the shoe guide 21' in the second embodiment have been modified. Specifically, the opposing first and second sidewalls 29', 31' of the shoe 19' each have a convex profile; and the opposing third and fourth sidewalls 33', 35' are substantially planar. The inner wall 53' of the shoe guide 21' is profiled to define four shoe guide faces 55'a-d for engaging a central section of the corresponding sidewalls 29', 31', 33', 35' of the shoe 19'. First and second lateral guide faces 55'a, b engage the respective first and second sidewalls 29', 31'; and third and fourth end guide faces 55'c, d engage the respective third and fourth sidewalls 33', 35'.

[0033] The shoe 19' and the shoe guide 21' are profiled to define four corner channels 59'. The corner channels 59' are defined by concave cut-outs formed in the inner wall 53' of the shoe guide 21'. As in the first embodiment, the corner channels 59' maintain the upper cambox 47' in fluid communication with the main cambox 49'. A perspective view of the shoe 19' is shown in Figure 5.

[0034] The operation of the pump 1' incorporating the shoe 19' and the shoe guide 21' according to the second embodiment is unchanged from that of the first embodiment. In particular, the corner channels 59' allow lubricant to travel between the upper cambox 47' and the main cambox 49'.

[0035] A shoe and shoe guide according to a third embodiment of the present invention is illustrated in Figure 6. The third embodiment is similar to the first embodiment described herein and like reference numerals will again be used for like components, albeit suffixed with two prime modifiers for clarity.

[0036] The sidewalls 29", 31", 33", 35" of the shoe 19" are substantially planar and a radius is formed at each corner. Four corner channels 59" are defined by concave cut-outs formed in the inner wall 53" of the shoe guide 21". As before, the corner channels 59" maintain the upper cambox in fluid communication with the main cambox. In addition, four shoe guide bores 61 are formed in the shoe guide 21". The shoe guide bores 61 are arranged substantially parallel with the longitudinal axis X and extend through the shoe guide 21". The shoe guide bores 61 thereby provide additional fluid pathways between the upper cambox and the main cambox.

[0037] The first, second and third embodiments described herein provide fluid pathways at the interface between the shoe 19 and the shoe guide 21 to enable lubricant to flow past the shoe 19. An alternate approach is to form one or more bores in the shoe 19. The shoe bores can extend through the shoe 19 thereby providing one or more fluid pathways between the upper and lower sides 25, 27 of the shoe 19. The shoe bores can facilitate the introduction of lubricant directly at the interface between the shoe 19 and the follower roller 39. By way of example, a modified shoe 19 having first and second

shoe bores 63 is illustrated in Figure 7. The upper and/or lower edges of the shoe bores 63 can be chamfered.

[0038] The embodiments described herein can utilise the liquid fuel being pumped by the high pressure fuel pump 1 to provide lubrication. Alternate arrangements may require a separate lubricant which is different from the liquid fuel. For example, the liquid fuel could be contained within the hydraulic head 7 and a separate lubricant provided for lubricating the pump 1. A modified embodiment of the high pressure fuel pump 1 described herein could provide a lubricant, such as oil, in the upper cambox 47 and the main cambox 49 for lubricating the pump 1. The liquid fuel to be pumped would be prevented from entering the upper cambox 47 and the main cambox 49 from the pumping chamber 17.

[0039] It will be appreciated that various changes and modifications can be made to the embodiment described herein without departing from the scope of the present invention.

Claims

1. A high pressure fuel pump assembly for an internal combustion engine, the pump assembly comprising:

a follower roller engageable with a cam provided on a rotatable driveshaft;
a shoe for reciprocating a fuel pump plunger;
and
a shoe guide having a guide face for guiding the shoe;
the shoe having an upper side and a lower side, a part cylindrical recess being formed on the lower side of the shoe for cooperating with the follower roller;
wherein at least one aperture is provided in the shoe guide and/or the shoe to form at least one fluid pathway for maintaining fluid communication between the upper and lower sides of the shoe.

2. A high pressure fuel pump as claimed in claim 1, wherein said at least one fluid pathway is suitable for maintaining fluid communication between an upper cambox and a main cambox of the pump assembly.

3. A high pressure fuel pump as claimed in claim 2 further comprising a bypass channel for providing fluid communication between the upper cambox and the main cambox.

4. A high pressure fuel pump as claimed in any one of claims 1, 2 or 3, wherein said at least one aperture comprises a first channel formed in a sidewall of the shoe.

5. A high pressure fuel pump as claimed in any one of claims 1 to 4, wherein said at least one aperture comprises a concave section formed in a sidewall of the shoe.

6. A high pressure fuel pump as claimed in any one of the preceding claims, wherein the shoe is elongated in a transverse direction and comprises two long sidewalls and two short sidewalls; said at least one aperture being formed in one or both of said long sidewalls.

7. A high pressure fuel pump as claimed in any one of the preceding claims, wherein said at least one aperture comprises a second channel formed in the shoe guide.

8. A high pressure fuel pump as claimed in claim 7, wherein said second channel is formed by a cut-out in an inner surface of the shoe guide.

9. A high pressure fuel pump as claimed in any one of the preceding claims, wherein said at least one aperture comprises a bore formed in the shoe and/or the shoe guide.

10. A high pressure fuel pump as claimed in claim 9, wherein said bore is coincident with the part cylindrical recess formed on the lower side of the shoe.

9. A shoe for cooperating with a follower roller in a high pressure fuel pump, the shoe having an upper side, a lower side and a sidewall; a part cylindrical recess being formed on the lower side of the shoe for receiving a follower roller; wherein at least one aperture is provided in said shoe for forming at least one fluid pathway to maintain fluid communication between the upper and lower sides of the shoe.

10. A shoe as claimed in claim 9, wherein said at least one aperture comprises a first channel formed in the sidewall of the shoe.

11. A shoe as claimed in claim 9 or claim 10, wherein said at least one aperture comprises a concave section formed in the sidewall of the shoe.

12. A shoe as claimed in any one of claims 9, 10 or 11, wherein the shoe is elongated in a transverse direction and comprises two long sidewalls, and two short sidewalls; said at least one aperture being formed in one or both of said long sidewalls.

13. A shoe as claimed in any one of claims 9 to 12, wherein said at least one aperture comprises a bore formed in the shoe; the bore optionally being coincident with the part cylindrical recess formed on the lower side of the shoe.

14. A shoe guide for guiding a shoe in a high pressure fuel pump, the shoe guide having an inner wall defining at least one guide face for engaging a sidewall of the shoe; wherein at least one aperture is provided in inner wall of the shoe guide for forming at least one fluid pathway past the shoe. 5

15. An assembly comprising a shoe as claimed in any one of claims 9 to 13 and a shoe guide as claimed in claim 14. 10

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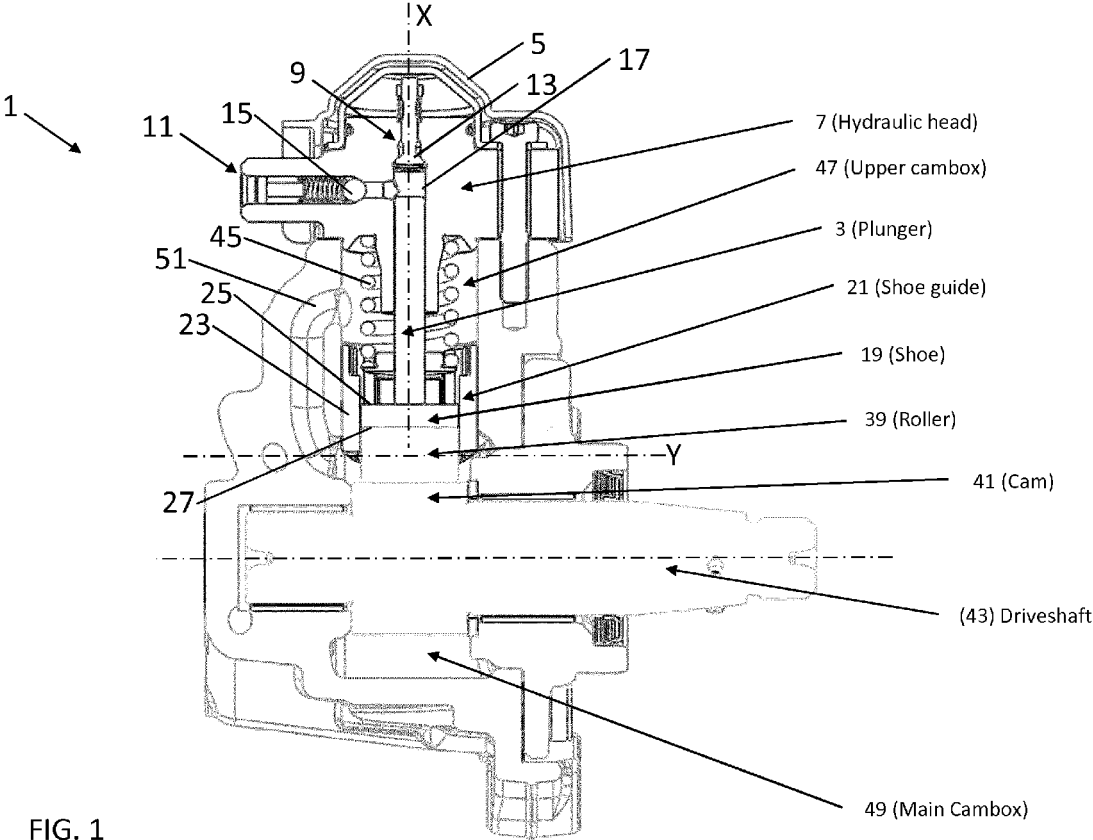
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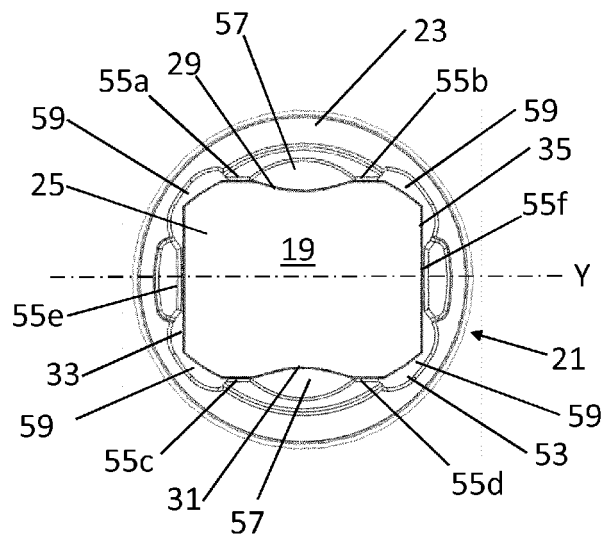


FIG. 2

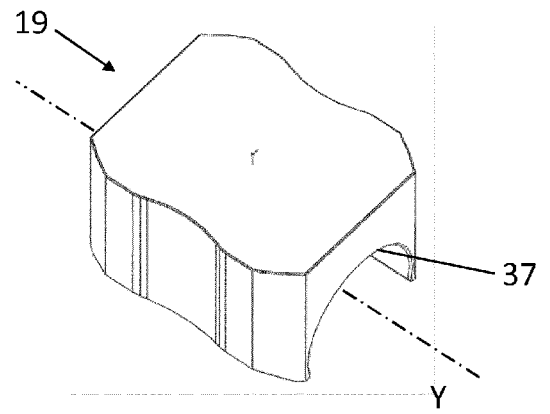
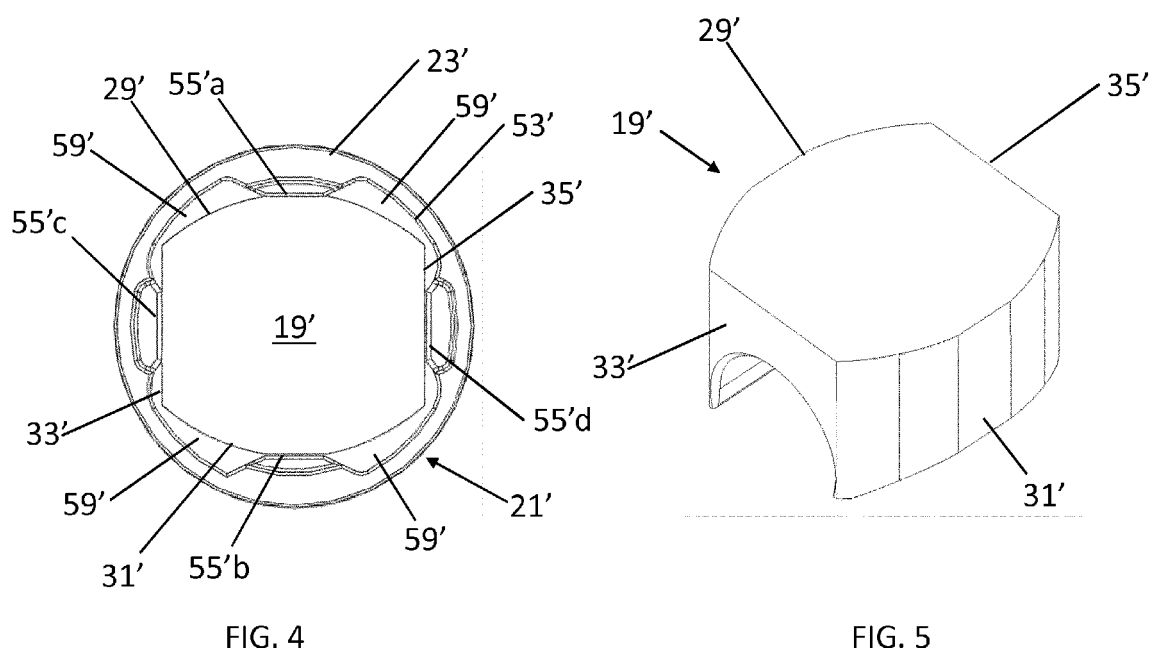


FIG. 3



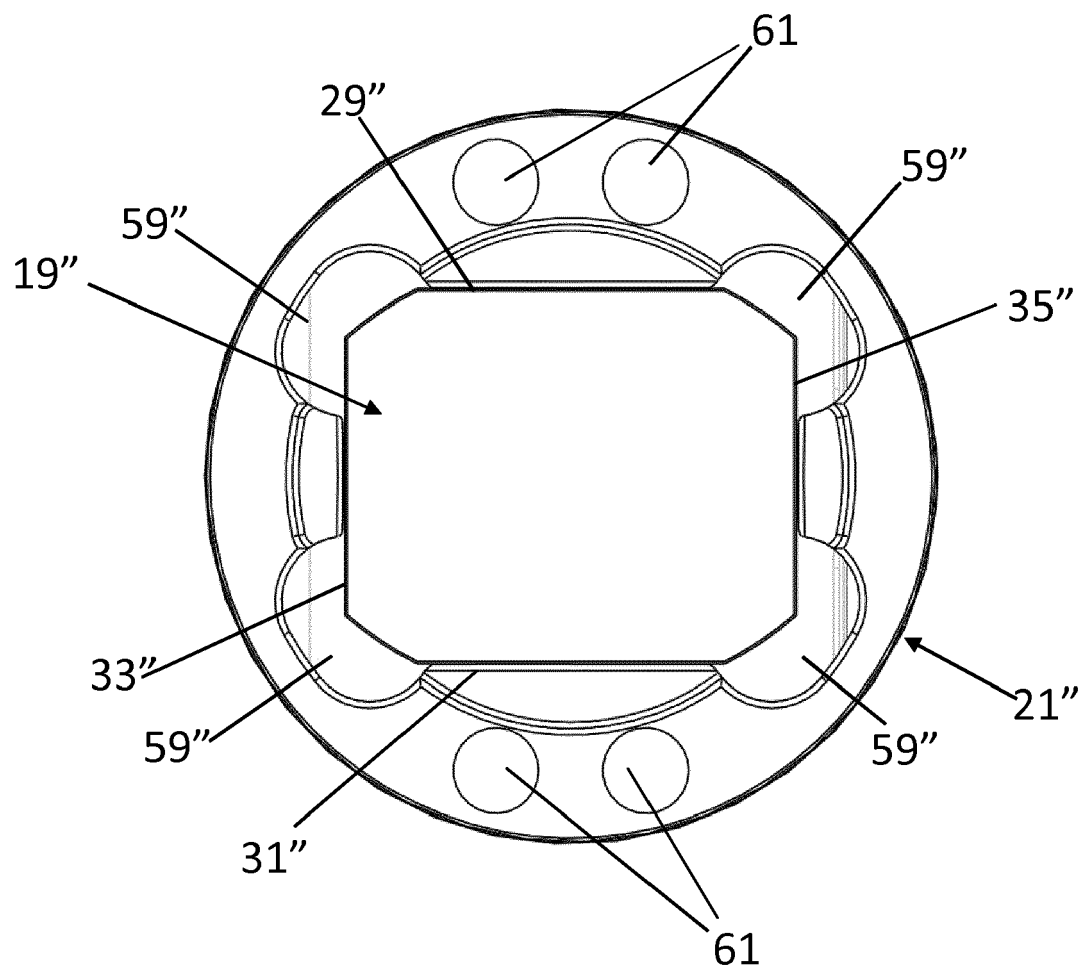


FIG. 6

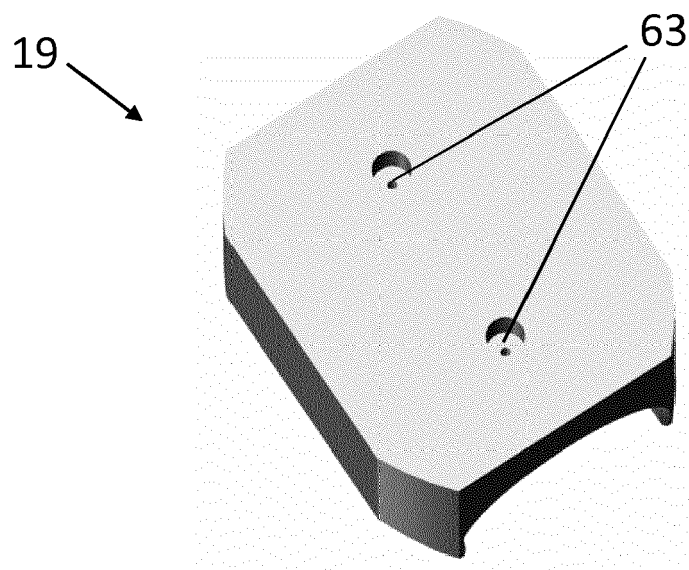


FIG. 7



EUROPEAN SEARCH REPORT

Application Number
EP 12 16 5506

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 October 2012	Examiner Etschmann, Georg
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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