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(54) **Pumping assembly**

(57) A pumping assembly (100; 200) suitable for use as a high-pressure fuel pump of a fuel injection system is disclosed. The pumping assembly comprises a cam (104; 204) arranged for eccentric rotation about a drive shaft axis (A), a cam rider (106; 206) mounted on the cam (104; 204), a cam follower (112; 212) arranged for reciprocal movement in a direction parallel to a cam follower axis (Q), the cam follower (112; 212) being cooperable with the rider (106; 206) by way of a sliding interface (110, 116; 210, 216) to define a sliding axis (S), and a pumping element associated with the cam follower (112; 212) and arranged to reduce the volume of a pumping chamber during a forward stroke and to increase the volume of the pumping chamber during a reverse stroke. The rider (106; 206) is driveable by the cam (104; 204) in a direction having a first component parallel to the cam follower axis (Q) and a second component in a direction perpendicular to the cam follower axis (Q). In one embodiment, the sliding axis (S) is inclined at a non-perpendicular angle to the cam follower axis (Q), such that both the first component and the second component of movement of the rider (106; 206) give rise to movement of the cam follower (112; 212) in the direction parallel to the cam follower axis (Q). In another embodiment, the cam follower (212) comprises first and second surfaces (216, 216a) that cooperate with the rider (206) at the first and second sliding interfaces (210, 216; 210a, 216a), respectively, and the forward stroke of the pumping element is driven when the rider (206) thrusts against the first surface (216) during movement of the rider (206) and the return stroke of the pumping element is driven when the

rider (206) thrusts against the second surface (216a) during movement of the rider (206).

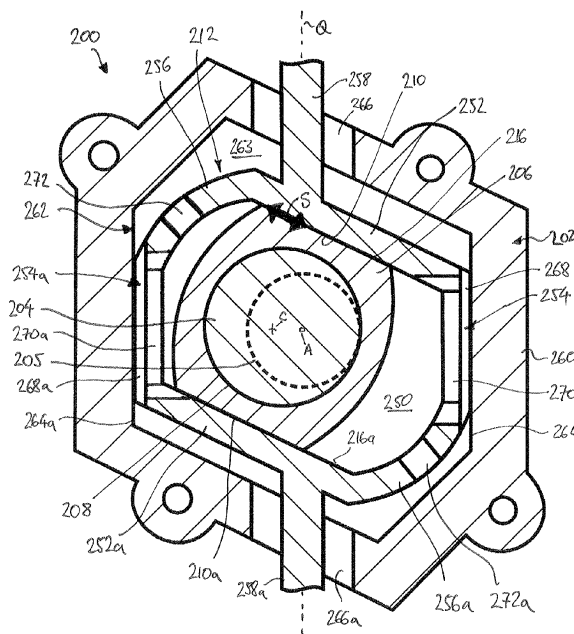


FIGURE 8

Description

Field of the invention

[0001] This invention relates to a pumping assembly for pumping a fluid. In particular, but not exclusively, the invention relates to a pumping assembly suitable for use in a high-pressure fuel pump of a fuel injection system for an internal combustion engine.

Background to the invention

[0002] Figure 1 of the accompanying drawings is a schematic diagram of a conventional fuel injection system 10 for an internal combustion engine.

[0003] The fuel injection system 10 comprises a plurality of fuel injectors 12. Each injector 12 is arranged to deliver an atomised spray of high-pressure fuel to a respective combustion chamber (not shown) of the engine. The injectors 12 receive fuel at high pressure from an accumulator volume or rail 14, by way of high-pressure supply lines 16. The rail 14 comprises a reservoir for high-pressure fuel.

[0004] Delivery of fuel from the injectors 12 is controlled by an electronic control unit 18. When a fuel injection from one of the injectors 12 is required, the electronic control unit 18 sends an actuation signal to the injector 12, which causes actuation of a delivery valve (not shown) of the injector 12.

[0005] Fuel is pumped to the rail 14 from a storage tank 20 by a fuel pump assembly 22. The fuel pump assembly 22 includes a low-pressure transfer pump 24, which serves to convey fuel from the tank 20 to the pump assembly 22, and a high-pressure pump 26 which elevates the pressure of the fuel to the injection pressure, typically of the order of 2000 bar. Fuel is conveyed from the tank 20 to the pump assembly 22 by way of a low-pressure fuel line 28, and from the pump assembly 22 to the rail by way of a high-pressure fuel line 30.

[0006] An inlet metering valve 32, under the control of the engine control unit 18, is provided between the transfer pump 24 and the high-pressure pump 26 of the pump assembly 22. The inlet metering valve 32 determines how much fuel reaches the high-pressure pump 26, for subsequent pressurisation and delivery to the rail 14. The fuel pressure in the rail 14 is regulated to a target value by the electronic control unit 18. A pressure-limiting valve 36 and return line 38 prevent the rail pressure exceeding a pre-determined acceptable level.

[0007] The high-pressure pump 26 comprises a pumping head 50, shown schematically in Figure 2, which is arranged to receive a reciprocable pumping plunger or pumping element 52. The pump 26 further comprises a drive assembly 54, shown schematically in Figure 3, for driving reciprocal movement of the pumping element 52. It should be noted that the cross-sectional views of the pumping head 50 and the drive assembly 54 in Figures 2 and 3 respectively are not to scale.

[0008] The pumping head 50 comprises a housing 56 that includes a blind bore 58. The pumping element 52 is slidably received within the bore 58. A pumping chamber 60 at the blind end of the bore 58 is defined in part by the pumping member 52 and in part by the bore 58. As the pumping element 52 is driven in reciprocal motion along a pumping axis Q by the drive assembly 54, the volume of the pumping chamber 60, and hence the pressure in the pumping chamber 60, increases and decreases accordingly.

[0009] The pumping head 50 further comprises a spring-biased inlet valve 62 and a spring-biased outlet valve 64. When the pumping element 52 moves downwards (referred to as a filling stroke or return stroke of the pumping element 52), the volume of the pumping chamber 60 increases, the outlet valve 64 closes, and the inlet valve 62 opens when the pressure differential across it reaches a first predetermined level. Fuel is then admitted to the pumping chamber 60 from a fuel supply passage 63, through the inlet valve 62. The fuel supply passage 63 is fed with fuel from the inlet metering valve (32 in Figure 1).

[0010] When the pumping element 52 moves upwards (referred to as a pumping stroke or forward stroke of the pumping element 52), the volume of the pumping chamber 60 decreases. The inlet valve closes 62, and the pressure of fuel in the pumping chamber 60 increases. The outlet valve 64 is arranged to open when the pressure differential across it reaches a second pre-determined level. Fuel is then delivered through the outlet valve 64 from the pumping chamber 60, for delivery to the fuel rail 14 through an outlet passage 65. By setting the second pre-determined differential pressure level at a high level, for example 2000 bar or more, the fuel rail 14 can be pressurised to a suitably high pressure for injection.

[0011] Referring to Figure 3, the drive assembly 54 comprises a housing 70, also known as a cam box, which houses a cylindrical cam 72. The housing 70 is only partially shown in Figure 3. The cam 72 is driven in eccentric rotational movement by a drive shaft (not shown in Figure 3) that extends through the housing 70, so that the cylinder axis C of the cam describes a circular path around the axis A of the drive shaft (which extends normal to the drawing plane in Figure 3) as the drive shaft rotates. The path described by the edge of the cam 72 as it rotates is indicated by the dashed line P in Figure 3. The drive shaft has a smaller diameter than the cam 72.

[0012] The cam 72 carries a cam ring or rider 74, which includes a central cylindrical aperture 76 for receiving the cam 72. The rider 74 includes a flattened surface region or flat 78, which is arranged to cooperate with a cam follower or tappet 80 that acts as a drive member for the pumping element 52. The cam 72 is free to rotate in the aperture 76, so that the orientation of the flat 78 of the rider 74 remains horizontal in use.

[0013] The tappet 80 is guided for reciprocal movement through an opening 82 in the housing 70, and is coupled to the pumping element 52 so that movement of

the tappet 80 causes movement of the pumping element 52.

[0014] The tappet 80 includes a flat base surface 84 that is held in sliding contact with the flat 78 of the cam rider 74 by a biasing spring 86. The housing 70 contains a lubricant (conveniently fuel) that lubricates the sliding interfaces between the tappet 80 and the rider 74 and between the tappet and the wall of the opening 82.

[0015] Operation of the drive assembly 54 will now be described with reference to Figures 4(a) to 4(c). In use, the drive shaft rotates about its axis A, in a clockwise direction in the figures, causing eccentric clockwise movement of the cam 72.

[0016] Two stages in the movement of the cam 72 from its lowermost position (bottom dead centre or BDC) to its uppermost position (top dead centre or TDC) are shown in Figures 4(a) and 4(b). As the drive shaft rotates, the cam 72 carries the rider 74 in a path having an upward component, towards the opening 82 in the housing 70. By virtue of the upward component of movement of the rider 74, the tappet 80, is driven upwards by the rider 74, so as to drive the forward stroke of the pumping element (52 in Figure 2).

[0017] Once the cam 72 reaches TDC, continued rotation of the drive shaft results in the cam 72 carrying the rider 74 in a path having a downward component, away from the opening 82 in the housing 70. The biasing spring 86 keeps the tappet 80 in engagement with the flat 78 of the rider 74, so that the tappet 80 moves downwards and the pumping element (52 in Figure 2) is therefore driven by the biasing spring 86 in its return stroke.

[0018] When the cam 72 reaches BDC, as shown in Figure 4(c), the pumping cycle repeats as the drive shaft continues to rotate.

[0019] During the pumping cycle, the flat 78 of the rider 74 slides laterally across the bottom surface 84 of the tappet 80 along a sliding axis (arrow S in Figure 3). The rider 74 moves from left to right in Figure 3 when the cam 72 moves from 90° before TDC to 90° after TDC, for example as shown in Figures 4(a) and 4(b), and from right to left when the cam 72 moves from 90° after TDC to 90° before TDC, for example as shown in Figure 4(c). Since lateral movement of the tappet 80 is constrained, the bottom surface 84 of the tappet 80 keeps the flat 78 of the rider 74 oriented in a plane normal to the pumping axis Q. Further guide means for the rider and/or the tappet 80 may be provided.

[0020] A second pumping head (not shown) may be mounted diametrically opposite the pumping head 50 shown in Figure 3. In this case, a pumping element (not shown) associated with the second pumping head is driven by a tappet (not shown) that cooperates with a second flat 78a provided on the rider 74. The second pumping head provides the high-pressure pump 26 with extra pumping capacity, and also helps to balance the moving components of the pump 26.

[0021] The maximum delivery pressure achievable by the high-pressure pump 26 depends, in part, on the

stroke length of the pumping element 52. The stroke length is the distance travelled by the pumping element 52 between the start and the end of the forward stroke. With a longer stroke length, the volume change of the pumping chamber 60 is greater, and so the fuel in the pumping chamber 60 is elevated to a higher pressure.

[0022] In general terms, there is a desire to be able to provide fuel to the injectors at increasing pressures, since increased injection pressure can help to improve injection control, emissions and fuel efficiency. Accordingly, it is desirable to maximise the stroke length of the pumping element 52 of a high-pressure pump 26.

[0023] In the configuration shown in Figure 3, in which the pumping axis Q intersects the drive shaft axis A, the stroke length is twice the distance between the drive shaft axis A and the cam axis C. The stroke length of the pumping element 52 can therefore be increased by increasing the offset distance between the drive shaft axis A and the cam axis C, and therefore the eccentricity of the cam 72 with respect to the drive shaft.

[0024] The maximum offset distance between the drive shaft axis A and the cam axis C is, in practice, equal to the difference between the radius of the cam 72 and the radius of the drive shaft, since otherwise the cam rider 74 would not be able to pass over the drive shaft during manufacture to reach the cam 72. Accordingly, to increase the maximum offset distance between the drive shaft axis A and the cam axis C, a larger-diameter cam 72 must be used.

[0025] This approach has disadvantages. Increasing the diameter of the cam 72 increases the inertia of the rotating components, and therefore decreases the efficiency of the pump 26 and potentially increases wear rates on the drive shaft bearings. Also, during assembly, the drive shaft and cam 72 must pass through an aperture in at least one wall of the housing 70. The drive shaft is held in a bearing in the aperture. The larger the cam 72, the larger the diameter of the bearing required, which increases the cost and complexity of the pump 26.

[0026] Another consideration in high-pressure fuel injection is that the high-pressure pump 26 must be able to deliver a sufficient quantity of fuel to the rail 14 to meet the demand from the fuel injectors 12. At particularly high engine loads, the fuel demand can be considerable. One solution to maintaining sufficient fuel output from the high-pressure pump 26 is to increase the drive speed of the drive shaft, to increase the rate of pumping.

[0027] The pumping rate can, however, be limited by the ability of the biasing spring 86 to keep the tappet 80 in contact with the rider 74 on the return stroke of the pumping element 52. Also, as the pumping rate increases, the risk of fatigue damage to the spring 86 increases.

[0028] Against this background, it would be desirable to provide pumping arrangements that offer an increase in output pressure and volume that overcome or reduce the problems described above.

Summary of the invention

[0029] From a first aspect, the present invention resides in a pumping assembly comprising a cam arranged for eccentric rotation about a drive shaft axis, a cam rider mounted on the cam, a cam follower arranged for reciprocal movement in a direction parallel to a cam follower axis, the cam follower being cooperable with the rider by way of a sliding interface to define a sliding axis, and a pumping element associated with the cam follower and arranged to reduce the volume of a pumping chamber during a forward stroke and to increase the volume of the pumping chamber during a reverse stroke.

[0030] The rider is driveable by the cam in a direction having a first component parallel to the cam follower axis and a second component in a direction perpendicular to the cam follower axis. The sliding axis is inclined at a non-perpendicular angle to the cam follower axis, such that both the first component and the second component of movement of the rider give rise to movement of the cam follower in the direction parallel to the cam follower axis.

[0031] Because both the first and second components of movement of the rider are converted into reciprocal linear motion of the cam follower, the distance moved by the cam follower in the direction parallel to the cam follower axis, and hence the stroke length of the pumping element during its forward and return strokes, is increased. In particular, the stroke length of the pumping element in a pumping assembly according to the first aspect of the invention is greater than the stroke length in a conventional arrangement having a cam with the same diameter and position with respect to the drive shaft axis, in which the sliding axis is perpendicular to the cam follower axis such that only the first component of movement of the rider is converted into reciprocal linear motion of the cam follower.

[0032] Accordingly, the present invention provides a pumping assembly capable of higher pressure and higher volume output than previously-known pumping assemblies in which the sliding axis is perpendicular to the cam follower axis.

[0033] In one embodiment, the cam follower axis is perpendicular to the drive shaft axis. The second component of movement of the rider may be perpendicular to the drive shaft axis.

[0034] The cam follower may be cooperable with the rider by way of first and second sliding interfaces that are parallel to the sliding axis. For example, the cam follower may comprise first and second surfaces that cooperate with the rider at the first and second sliding interfaces, respectively. Advantageously, the forward stroke of the pumping element may be driven when the rider thrusts against the first surface during movement of the rider and the return stroke of the pumping element is driven when the rider thrusts against the second surface during movement of the rider. In this way, both the forward stroke and the return stroke of the pumping element are driven by

the cam, by way of the rider and the cam follower. Advantageously, therefore, it is not necessary to provide a biasing spring to keep the cam follower in contact with the rider.

[0035] The present invention also resides, in a second aspect, to a pumping assembly that comprises a cam arranged for eccentric rotation about a drive shaft axis, a cam rider that cooperates with the cam, a cam follower arranged for reciprocal movement in a direction parallel to a cam follower axis that is perpendicular to the drive shaft axis, and a pumping element associated with the cam follower and arranged to reduce the volume of a pumping chamber during a forward stroke and to increase the volume of the pumping chamber during a reverse stroke.

[0036] The cam follower comprises first and second surfaces that cooperate with the rider at first and second sliding interfaces, respectively. The forward stroke of the pumping element is driven when the rider thrusts against the first surface during movement of the rider and the return stroke of the pumping element is driven when the rider thrusts against the second surface during movement of the rider. Preferably, the cam rider is mounted on the cam.

[0037] In this second aspect of the invention, both the forward stroke and the return stroke of the pumping element are driven by the cam, by way of the rider and the cam follower. Accordingly, it is not necessary to provide a biasing spring to keep the cam follower in contact with the rider. Therefore, since the maximum rate of pumping is not limited by the capabilities of a biasing spring, the pumping assembly of the second aspect of the invention can operate at an increased pumping rate. Furthermore, because a force is applied to the cam follower by the cam throughout the whole pumping cycle, smooth and stable reciprocal movement of the cam follower and the pumping element can be achieved.

[0038] In either aspect of the invention, when the cam follower comprises first and second surfaces that cooperate with the rider at first and second sliding interfaces, respectively, the cam follower may include a first cross member comprising the first surface and a second cross member comprising the second surface. The first and second cross members may be disposed on opposite sides of the rider.

[0039] The cam follower may include at least one connecting member that connects the first cross member to the second cross member. The cam follower may define, at least in part, a volume for receiving the rider and the cam. The volume may receive a lubricating fluid, such as a fuel, in use of the pumping assembly.

[0040] In one embodiment, the cam follower comprises first and second connecting members that connect respective ends of the first cross member to corresponding ends of the second cross member, such that the first and second cross members and the first and second connecting members define, at least in part, the volume for receiving the rider and the cam.

[0041] The sliding interface may comprise at least one flattened region of the rider for cooperation with a surface of the cam follower.

[0042] The pumping assembly may further comprise a housing that receives the cam, the rider and the cam follower. Conveniently, the housing guides the cam follower for reciprocal movement in a direction parallel to the cam follower axis. For example, the cam follower may include guide members arranged in sliding contact with a wall of the housing for guiding the reciprocal movement of the cam follower. The guide members may comprise the connecting members that connect the respective ends of the first cross member to corresponding ends of the second cross member, when present.

[0043] The cam follower may comprise a first drive member for driving the pumping element, wherein the drive member extends out of the housing. The cam follower may further comprise a second drive member for driving a further pumping element, in which case the second drive member may extend out of the housing in an opposite direction to the first drive member. The or each drive member may be integral with or connected to the cam follower, and/or integral with or connected to the pumping element.

[0044] The pumping assembly may include fluid flow means for permitting fluid flow through or past the rider and/or the cam follower during movement of the rider and/or the cam follower. For example, the fluid flow means may comprise at least one fluid flow passage in the cam follower.

[0045] In another aspect, the invention resides in a high-pressure fuel pump for a fuel injection system, comprising a pumping assembly according to the first or second aspects of the invention, and a pump head that includes the pumping chamber.

[0046] Preferred and/or optional features of each aspect of the invention may be used alone or in appropriate combination in the other aspects of the invention also.

Brief description of the drawings

[0047]

Figure 1 of the accompanying drawings, which has been referred to above, is a schematic diagram of a conventional fuel injection system of an internal combustion engine having a conventional high-pressure fuel pump.

Figures 2 and 3, which have also been referred to above, are schematic cross-sectional views of a pumping head and a drive assembly, respectively, of a conventional high-pressure fuel pump for use in the fuel injection system of Figure 1.

Figures 4(a) to 4(c) are schematic cross-sectional views that illustrate the operation of the conventional drive assembly of Figure 3.

[0048] Embodiments of the present invention will now be described, by way of example only, with reference to the remaining accompanying drawings, in which like reference numerals are used for like features, and in which:

Figure 5 is a schematic cross-sectional view of a pumping arrangement according to a first embodiment of the present invention;

Figures 6(a) to 6(c) are schematic cross-sectional views illustrating the operation of the pumping arrangement of Figure 5;

Figure 7 is a schematic graph illustrating the relationship between displacement and cam rotation angle for a pumping arrangement such as that shown in Figure 5, compared to a conventional pumping arrangement;

Figure 8 is a schematic cross-sectional view of a pumping arrangement according to a second embodiment of the present invention;

Figures 9(a), 9(b) and 9(c) are front, side and perspective views of a cam follower of the pumping arrangement of Figure 8; and

Figure 10 is a schematic cross-sectional view of a pumping arrangement according to a third embodiment of the present invention.

[0049] Throughout this description, terms such as 'upper', 'lower', 'left', 'right', 'horizontal', 'vertical' and so on relate to the orientation of the components as shown in the accompanying drawings and are used for ease or reference only. It should be understood that the invention could be used in any suitable orientation.

Detailed description of embodiments of the invention

[0050] Figure 5 shows a drive assembly 100 for a pumping arrangement, for use as a high-pressure fuel pump in a fuel injection system.

[0051] The drive assembly 100 includes a housing 102, only part of which is shown in Figure 5, which houses a cylindrical cam 104. The cam 104 is mounted eccentrically on a drive shaft (not shown in Figure 5), so that the cylinder axis C of the cam 104 is parallel to, but offset from, the axis A of the drive shaft. In use, when the drive shaft rotates, the cam 104 rotates eccentrically so that the outermost edge of the cam 104 describes a path shown by the dashed line P in Figure 5.

[0052] The cam 104 carries a cam ring or rider 106. The cam 104 is received in a cylindrical aperture 108 in the rider 106. The rider 106 includes first and second flattened regions or flats 110, 110a, disposed either side of the aperture 108. The flats 110, 110a are parallel to

one another, and are inclined at an angle with respect to the horizontal in the orientation shown in Figure 5.

[0053] A tappet or cam follower 112 is slidably received in an aperture 114 in the housing 102. The cam follower 112 is guided for linear reciprocal movement by the aperture 114 along a pumping axis Q. The cam follower 112 includes a drive member 158 that is coupled to a pumping element (not shown), such as a pumping plunger, that cooperates with a suitable pumping head mounted outside the housing 102. For example, a known pumping head such as that shown in Figure 2 may be provided.

[0054] The pumping element is driven in reciprocal motion by the cam follower 112 so as to pump fluid to an outlet of the pumping head at high pressure during a forward or pumping stroke, and to draw fluid into the pumping head from an inlet during a return or filling stroke. The operation of the pumping head is as described above with reference to Figure 2.

[0055] Returning to Figure 5, the cam follower 112 includes an end surface 116 that is inclined to the horizontal in the orientation shown in Figure 5. The angle of inclination of the flats 110, 110a of the rider 106 matches the angle of inclination of the end surface 116 of the cam follower 112, so the end surface 116 of the cam follower 112 is in sliding contact with the uppermost flat 110 of the rider 106, to define a sliding interface between the rider 106 and the cam follower 112. Contact between the end surface 116 of the cam follower 112 and the flat 110 is maintained by a biasing spring (not shown).

[0056] By virtue of the inclination of the cam follower end surface 116 and the flat 110, the sliding interface between the rider 106 and the cam follower 112 lies in a plane having a normal direction that is inclined at an angle to the pumping axis Q. Said another way, the rider 106 and the cam follower 112 slide with respect to one another along a sliding axis (indicated by arrow S) that is inclined at a non-perpendicular angle to the pumping axis. The cam 104 is rotatable relative to the rider 106 so that the orientation of the rider 106 remains constant in use.

[0057] Operation of the pumping mechanism of Figure 5 will now be described with reference to Figures 6(a) to 6(c), which show successive stages in operation as the drive shaft rotates in a clockwise direction.

[0058] Figure 6(a) shows the mechanism when the cam 104 is approximately mid-way between bottom dead centre (BDC) and top dead centre (TDC). As the cam 104 rotates in a clockwise direction, towards TDC, the rider moves in a direction having an upward component of movement and a horizontal component of movement (to the right in Figure 6(a)). The flat 110 of the rider 106 slides along the end surface 116 of the cam follower 112, so that the rider 106 moves to the right in the drawings relative to the cam follower 112.

[0059] By virtue of the angled orientation of the flat 110, both the upward and the horizontal components of movement of the rider 106 result in upward movement of the cam follower 112, and drive the forward stroke of

the pumping element.

[0060] Figure 6(b) shows the drive assembly when the cam 104 has reached a position just after TDC. The rider 106 is now moving in a direction having a downward component of movement and a horizontal component of movement (to the right in Figure 6(b)). If the flat 110 were horizontal, in this position the cam follower 112 would be at a lower position than when the cam 104 is at TDC. However, because of the angled orientation of the flat 110, in the position shown in Figure 6(b) the cam follower 112 has moved further upwards, because the rider 106 has moved further to the right with respect to the cam follower 112. Therefore the inclination of the flat 110 increases the upward displacement of the cam follower 112, and hence increases the length of the pumping stroke of the pumping element.

[0061] Figure 6(c) shows the drive assembly when the cam 104 has reached a position approximately 45° before BDC. The rider 106 is now moving in a direction having a downward component of movement and a horizontal component of movement (towards the left in Figure 6(c)). The rider 106 moves to the left with respect to the cam follower 112, so that both the downward and horizontal components of movement of the rider 106 give rise to downward movement of the cam follower 112, thereby driving the return stroke of the pumping element under the influence of the biasing spring.

[0062] As the cam 104 passes BDC, the cam rider 106 is still moving towards the left, so that the cam follower 112 continues to move downwards. Thus the inclination of the flat 110 also increases the downward displacement of the cam follower 112, and hence increases the length of the return stroke of the pumping element.

[0063] Figure 7 is a graph showing the relative displacement of the cam follower 112 with respect to cam angle, where a cam angle of 0° or 360° represents TDC and a cam angle of 180° represents BDC. The solid line marked "I" in Figure 7 corresponds to a drive mechanism as shown in Figures 5 to 6(c), in which the sliding axis S is inclined at an angle of 25° to the horizontal (equivalent to an angle of 65° to the pumping axis Q). For comparison, the dashed line marked "H" in Figure 7 corresponds to a drive mechanism such as that shown in Figure 3, in which the sliding axis is at an angle of 90° to the pumping axis Q (i.e., in Figure 3, the sliding axis S between the tappet 80 and the rider 74 is perpendicular to the pumping axis Q).

[0064] From a comparison of lines "I" and "H" in Figure 7, it can be seen that in an arrangement having a sliding axis S that is inclined at a non-perpendicular angle to the pumping axis Q, the cam follower undergoes an increased displacement, and hence the pumping stroke is longer, compared to a conventional arrangement with a sliding axis S that is perpendicular to the pumping axis Q. The maximum positive and negative displacements of the cam follower occur after TDC and after BDC, respectively, and are shifted by an angle equal to the inclination of the normal of the sliding interface plane to the

pumping axis Q. In this example, therefore, the maximum positive and negative displacements occur 25° after TDC and BDC, respectively.

[0065] Although only one cam follower 112 is shown in Figures 5 to 6(c), it will be appreciated that a second cam follower with an associated pumping element and pumping head could be provided, to cooperate with the lowermost flat 110a of the rider 106.

[0066] It will be appreciated that an arrangement such as that shown in Figures 5 to 6(c), in which the flats 110, 110a of the rider 106 are inclined or slanted, will give rise to an increased side-loading on the cam follower 112 during operation, compared to a conventional arrangement in which the flats lie in a plane that is normal to the pumping direction. Furthermore, the rider 106 is free to rotate on the cam 104, and so the cam follower 112 acts to keep the rider 106 in the correct orientation in use.

[0067] Accordingly, care must be taken to guide the cam follower 112 in linear movement, and to avoid excessive wear of the cam follower 112, particularly where the cam follower surface 116 meets the flat 110.

[0068] As will be understood by a person skilled in the art, suitable guide means may be provided to guide linear movement of the cam follower 112. In one example, a linear bearing sleeve can be used to guide movement of the follower 112 in the housing aperture 114. In another example, the cam follower 112 comprises guide means in the form of guiding members that extend laterally in opposite directions from the follower 112 to engage slidably with internal walls of the housing 102.

[0069] Another example of suitable guide means is embodied in a drive assembly 200 according to a second embodiment of the invention, which is shown in cross-section in Figure 8.

[0070] The drive assembly 200 of Figure 8 includes a housing 202, which houses a cylindrical cam 204. The cam 204 is mounted eccentrically on a drive shaft, the position of which is indicated by the dashed line 205 in Figure 8. As in the first embodiment of the invention, the cylinder axis C of the cam 204 is parallel to, but offset from, the axis A of the drive shaft. In use, when the drive shaft rotates, the cam 204 rotates eccentrically so that the outermost edge of the cam 204 describes a path shown by the dashed line P in Figure 8.

[0071] The cam 204 carries a cam ring or rider 206. The cam 204 is received in a cylindrical aperture 208 in the rider 206. The rider 206 includes parallel first and second flattened regions or flats 210, 210a, disposed either side of the aperture 208.

[0072] A cam follower 212 cooperates with the rider 206, and is guided for linear reciprocal movement along a pumping axis Q, as will be described in more detail below. In this second embodiment of the invention, the cam follower 212 defines an internal volume 250, in which the rider 206 is slidably received.

[0073] Referring additionally to Figures 9(a), 9(b) and 9(c), which show the cam follower 212 of the drive assembly 200 of Figure 8 in isolation, the cam follower 212

includes a first or upper inclined member 252 and a parallel second or lower inclined member 252a, each of which extends at a non-perpendicular angle to the pumping axis Q. The cam follower further includes a first vertical member 254 that extends downwardly from the right-hand end of the first inclined member 252, and a second vertical member 254a that extends upwardly from the left-hand end of the second inclined member 252a. A first curved link member 256 joins the left-hand end of the first inclined member 252 to the top end of the second vertical member 254a, and a second curved link member 256a joins the right-hand end of the second inclined member 252a to the bottom end of the first vertical member 254.

[0074] In this way, the inclined members 252, 252a, the vertical members 254, 254a and the link members 256, 256a define a cage-like structure that encloses the volume 250, and the rider 206, therewithin. The volume 250 is open to the front and rear faces of the cam follower 212.

[0075] As illustrated in Figure 8, the angle of inclination of the flats 210, 210a of the rider 206 matches the angle of inclination of the inclined members 252, 252a of the cam follower 212, so a lower surface 216 of the first inclined member 252 of the cam follower 212 is in sliding contact with the uppermost flat 210 of the rider 206, and so an upper surface 216a of the second inclined member 252a is in sliding contact with the lowermost flat 210a. Therefore two sliding interfaces are defined between the rider 206 and the cam follower 212, each lying in a plane having a normal direction that is inclined at an angle to the pumping axis Q. As in the first embodiment of the invention, in this second embodiment, the rider 206 and the cam follower 212 slide with respect to one another along a sliding axis S that is inclined at a non-perpendicular angle to the pumping axis Q. The cam 204 is rotatable relative to the rider 206.

[0076] First and second drive members 258, 258a project upwardly and downwardly from the first and second inclined members 252, 252a, respectively. Each drive member 258, 258a cooperates with an associated pumping element (not shown). The drive assembly 200 is provided with an upper and a lower pumping head, disposed opposite one another across the drive shaft axis A, and each pumping head receives a respective upper and lower one of the pumping elements. The pumping heads may be of a known type, such as that described above with reference to Figure 2.

[0077] Referring again to Figure 8, the housing 202 comprises a wall part 260, which is visible in cross-section in Figure 8, and front and rear face plates (not shown) that are attachable to the front and rear sides of the wall part 260. The face plates include apertures that allow the drive shaft to pass through the housing 202.

[0078] The wall part 260 of the housing 202 has an irregular generally hexagonal cross-section, and an inner wall 262 of the wall part 260 defines a housing volume 263 in which the cage-like structure of the cam follower

212 is received. The inner wall 262 includes first and second vertical guide surfaces 264, 264a, and the first and second vertical members 254, 254a respectively of the cam follower 212 are in sliding contact with the vertical guide surfaces 264, 264a. The inclined members 252, 252a and the link members 256, 256a of the cam follower 212 are spaced from the inner wall 262 of the housing wall part 260, so that the cam follower 212 can move up and down within the housing volume 263.

[0079] The housing wall part 260 includes first and second apertures 266, 266a, through which the drive members 258, 258a extend. The drive members 258, 258a, are a clearance fit in the apertures 266, 266a, and so in this embodiment the cam follower 212 is not guided by cooperation with the housing 202 at the apertures 266, 266a, but instead by cooperation between the vertical members 254, 254a of the cam follower 212 and the internal vertical guide surfaces 262, 262a of the housing 202.

[0080] Referring back to Figures 9(a) to (c), the front face 269 of the cam follower 212 and the rear face 269a of the cam follower 212 are in sliding engagement with the internal surfaces of the front and rear face plates (not shown) of the housing 202 in use. Accordingly, cooperation between the front and rear faces 269, 269a of the cam follower 212 and the face plates of the housing 202 also acts to guide the movement of the cam follower 212.

[0081] In use, the housing volume 263 and the volume 250 defined by the cam follower 212 contain lubricating fluid, such as fuel, which lubricates the sliding interfaces between the vertical members 254, 254a of the cam follower 212 and the guide walls 262, 262a of the housing 202, the sliding interfaces between the inclined members 252, 252a of the housing cam follower 212 and the flats 210, 210a of the rider 206, and also the sliding interfaces between the front and rear faces 269, 269a of the cam follower 212 and the front and rear face plates of the housing 202. It will be appreciated that, in use, the sizes of the housing volume 263 and the cam follower volume 250 change cyclically as the cam follower 212 moves with respect to the housing 202, and as the rider 206 moves with respect to the cam follower 212.

[0082] To allow the fluid to flow freely within and between the volumes 250, 263 in operation, the cam follower 212 is provided with fluid flow means. The fluid flow means include vertically-extending recesses or channels 268, 268a in the outer surfaces of the first and second vertical members 254, 254a of the cam follower 212. One channel 268 extends from the first inclined member 252 to the second link member 256a, and the other channel 268a extends from the second inclined member 252a to the first link member 256. The channels 268, 268a allow fluid to flow past the cam follower 212 as it moves up and down within the housing volume 263.

[0083] The fluid flow means further includes first and second slots 270, 270a that extend through the first and second vertical members 254, 254a, respectively, of the cam follower 212, to communicate with the respective

channel 268, 268a. In addition, the fluid flow means includes first and second drillings 272, 272a, that extend through the first and second link members 256, 256a of the cam follower 212, respectively. The slots 270, 270a and drillings 272, 272a allow fluid transfer between the volume 250 defined by the cam follower 212 and the housing volume 263.

[0084] Operation of the drive assembly 200 of the second embodiment of the invention is conceptually similar to the operation of the drive assembly 100 of the first embodiment of the invention, as described with reference to Figures 4(a) to 4(c). In particular, by virtue of the inclination of the flats 210, 210a of the rider 206 and of the inclined members 252, 252a of the cam follower 212, both the vertical and horizontal components of movement of the rider 206 are converted to movement of the cam follower 212 in a direction parallel to the pumping axis Q. Accordingly, as in the first embodiment of the invention, this second embodiment has the advantage that the displacement of the cam follower 212, and hence the length of the pumping stroke, is larger than would be achieved using a conventional rider with a horizontal sliding interface between the rider and the cam follower.

[0085] Additionally, because movement of the cam follower 212 is guided by sliding interfaces between the front and rear faces 269, 269a of the cam follower 212 and the front and rear face plates of the housing 202, and particularly between the vertical members 254, 254a of the cam follower 212 and the guide walls 262, 262a of the housing 202, lateral loadings that arise from the inclination of the sliding axis S are borne by the housing 202 without affecting the cam follower 212.

[0086] A further advantage of the second embodiment of the invention arises because the rider 206 is embraced between the inner faces of the first and second inclined members 252, 252a of the cam follower 212. When the rider 206 moves against the first inclined member 252, the first drive member 258 moves upwards, driving the forward stroke of the upper pumping element. The second drive member 258a also moves upwards, driving the return stroke of the lower pumping element. When the rider 206 moves against the second inclined member 252a, the first and second drive members 258, 258a both move downwards, driving the return stroke of the upper pumping element and the pumping stroke of the lower pumping element, respectively.

[0087] Accordingly, both the forward and return strokes of both pumping elements are driven by the cooperative movement of the rider 206 against the cam follower 212. The drive assembly 200 of the second embodiment of the invention does not therefore require biasing springs or other biasing means for driving the return strokes of the pumping elements. Instead, the cam follower 212 remains engaged with the rider 206 by virtue of the cage-like arrangement of the cam follower 212, and equal force is applied to the drive members 258, 258a in both the forward and return strokes. As a result, the drive assembly 200 of the second embodiment of the

invention can be operated at higher speeds and has a higher resistance to fatigue damage than conventional drive assemblies.

[0088] It will be appreciated that the drive assembly 200 of Figure 8 would still offer the advantages of a biasing spring-free pumping arrangement even if the flats of the rider were horizontally oriented for cooperation with horizontal members of a cage-like cam follower. Such an arrangement is illustrated in Figure 10, which is a schematic cross-sectional view of a drive assembly 300 according to a third embodiment of the present invention.

[0089] The drive assembly 300 of Figure 10 includes a housing 302, which houses a cylindrical cam 304. The cam 304 is mounted eccentrically on a drive shaft, the position of which is indicated by the dashed line 305 in Figure 10. As in the first and second embodiments of the invention, the cylinder axis C of the cam 304 is parallel to, but offset from, the axis A of the drive shaft.

[0090] As in previous embodiments of the invention, the cam 304 carries a cam ring or rider 306 that includes parallel first and second flattened regions or flats 310, 310a, disposed either side of a cam-receiving aperture 308. The cam 304 is rotatable relative to the rider 306.

[0091] A cam follower 312 cooperates with the rider 306, and is guided for linear reciprocal movement along a pumping axis Q. The cam follower 312 defines an internal volume 350, in which the rider 306 is slidably received.

[0092] The cam follower 312 includes a first or upper horizontal member 352 and a parallel second or lower horizontal member 352a, each of which extend in a plane that lies normal to the pumping axis Q. The cam follower further includes a first vertical member 354 that connects the right-hand ends of the horizontal members 352, 352a, and a second vertical member 354a that connects the left-hand ends of the horizontal members 352, 352a. The vertical and horizontal members 352, 352a; 354, 354a define a cage-like structure that encloses the volume 350, and the rider 306, therewithin. The volume 350 is open to the front and rear faces of the cam follower 312, but is closed by front and rear face plates (not shown) of the housing 302.

[0093] A lower surface 316 of the first horizontal member 352 of the cam follower 312 is in sliding contact with the uppermost flat 310 of the rider 306, and an upper surface 316a of the second horizontal member 352a is in sliding contact with the lowermost flat 310a. Therefore two sliding interfaces are defined between the rider 306 and the cam follower 312, each lying in a plane having a normal direction that is parallel to the pumping axis Q.

[0094] First and second drive members 358, 358a project upwardly and downwardly from the first and second horizontal members 352, 352a, respectively, through apertures 366, 366a in the housing 302. As in the second embodiment of the invention, in this third embodiment each drive member 358, 358a cooperates with an associated pumping element (not shown). The drive assembly 300 is provided with an upper and a lower pumping head,

disposed opposite one another across the drive shaft axis A, and each pumping head receives a respective upper and lower one of the pumping elements. The pumping heads may be of a known type, such as that described above with reference to Figure 2.

[0095] The housing 302 comprises a wall part 360, which is visible in cross-section in Figure 10, and front and rear face plates (not shown) that are attachable to the front and rear sides of the wall part 360. The face plates include apertures that allow the drive shaft to pass through the housing 302.

[0096] In this embodiment, the wall part 360 of the housing 302 has a generally square cross-section, and an inner wall 362 of the wall part 360 defines a generally cuboidal housing volume 363 in which the cage-like structure of the rider 312 is received. The inner wall 362 includes first and second vertical guide surfaces 364, 364a, and the first and second vertical members 354, 354a respectively of the cam follower 312 are in sliding contact with the vertical guide surfaces 364, 364a. The cam follower 312 can therefore move up and down in guided movement within the housing volume 363.

[0097] As in the second embodiment of the invention, the front and rear faces (not shown) of the cam follower 312 are in sliding contact with the internal surfaces of the front and rear face plates (not shown) of the housing 302 in use. Accordingly, cooperation between the front and rear faces of the cam follower 312 and the face plates of the housing 302 also acts to guide the movement of the cam follower 312.

[0098] To allow lubricating fluid within the housing 302 to flow freely within and between the volumes 350, 363 in operation, the cam follower 312 is provided with fluid flow means in the form of vertically-extending channels 368, 368a in the outer surfaces of the first and second vertical members 354, 354a of the cam follower 312, first and second slots 370, 370a that extend through the first and second vertical members 354, 354a, respectively, and first and second drillings 372, 372a, that extend through the first and second horizontal members 354, 354a of the cam follower 312, respectively.

[0099] Operation of the drive assembly 300 of the third embodiment of the invention is similar to the operation of the drive assembly 200 of the second embodiment of the invention, as described above. However, in this third embodiment, because the flats 310, 310a of the rider 306 and the horizontal members 352, 352a of the cam follower 312 slide along sliding axes (S) that are perpendicular to the pumping direction Q, only the vertical component of movement of the rider 306 is converted to movement of the cam follower 312 in a direction parallel to the pumping axis Q. The length of the pumping stroke is therefore equal to twice the offset between the drive shaft axis A and the cam axis C.

[0100] Like in the second embodiment, in this third embodiment of the invention, both the forward and return strokes of both pumping elements are driven by the cooperative movement of the rider 306 against the cam

follower 312. The drive assembly 300 of the third embodiment of the invention advantageously does not therefore require biasing springs or other biasing means for driving the return strokes of the pumping elements.

[0101] It will be appreciated that the embodiments described above are examples only of the present invention, and that many variations and modifications are possible.

[0102] For example, in the embodiments described above, a drive member of the cam follower cooperates with a pumping element. The drive member and pumping element may be integrally formed, for example so that a distal end of the drive member forms the pumping element. The pumping element may instead be a separate component that is attached to or otherwise connected to the drive member. Similarly, the drive member may be a separate component that is attached to the cam follower. The pumping element, the drive member and the cam follower may be integrally formed as one component.

[0103] Similarly, the members that make up the cage-like cam follower in the second and third embodiments of the invention may be parts of a single, integrally formed component, or may be separate or combined components that are assembled to form the cam follower.

[0104] In the second and third embodiments of the invention, the fluid flow means that allow fluid flow past the cam follower as it reciprocates within the housing volume may be embodied in a different form to the channels described above. For example, channels or flow passages could be provided in the housing wall, in addition to or instead of the channels in the cam follower faces. Further channels, drillings and other flow passages could be provided in the cam follower, and flow means could also be provided in the rider or in the faces of the cam follower that cooperate with the rider to allow flow past the rider as it reciprocates.

[0105] The cam follower may take any suitable form. For example, in the second and third embodiments of the invention, the cam follower may be of any suitable design that provides two parallel faces for sliding engagement with the flats of the rider, and means for guiding the cam follower in linear reciprocal movement.

[0106] Although the pumping assembly of the present invention is particularly suitable for use as a high-pressure fuel pump of a fuel injection system, it will be appreciated that the pumping assembly could also be used for any other pumping application with similar requirements.

[0107] Many other modifications and variations of the invention not explicitly disclosed above could also be contemplated by a person skilled in the art without departing from the scope of the invention as defined in the appended claims.

Claims

1. A pumping assembly (100; 200), comprising:

a cam (104; 204) arranged for eccentric rotation about a drive shaft axis (A);
a cam rider (106; 206) mounted on the cam (104; 204);
a cam follower (112; 212) arranged for reciprocal movement in a direction parallel to a cam follower axis (Q), the cam follower (112; 212) being cooperable with the rider (106; 206) by way of a sliding interface (110, 116; 210, 216) to define a sliding axis (S); and
a pumping element associated with the cam follower (112; 212) and arranged to reduce the volume of a pumping chamber during a forward stroke and to increase the volume of the pumping chamber during a reverse stroke;
wherein the rider (106; 206) is driveable by the cam (104; 204) in a direction having a first component parallel to the cam follower axis (Q) and a second component in a direction perpendicular to the cam follower axis (Q);
and wherein the sliding axis (S) is inclined at a non-perpendicular angle to the cam follower axis (Q), such that both the first component and the second component of movement of the rider (106; 206) give rise to movement of the cam follower (112; 212) in the direction parallel to the cam follower axis (Q).

2. A pumping assembly according to Claim 1, wherein the cam follower (212) is cooperable with the rider (206) by way of first and second sliding interfaces (210, 216; 210a, 216a) that are parallel to the sliding axis (S).

3. A pumping assembly according to Claim 2, wherein the cam follower (212) comprises first and second surfaces (216, 216a) that cooperate with the rider (206) at the first and second sliding interfaces (210, 216; 210a, 216a), respectively, and wherein the forward stroke of the pumping element is driven when the rider (206) thrusts against the first surface (216) during movement of the rider (206) and the return stroke of the pumping element is driven when the rider (206) thrusts against the second surface (216a) during movement of the rider (206).

4. A pumping assembly (200; 300), comprising:

a cam (204; 304) arranged for eccentric rotation about a drive shaft axis (A);
a cam rider (206; 306) that cooperates with the cam (204; 304);
a cam follower (212; 312) arranged for reciprocal movement in a direction parallel to a cam follower axis (Q) that is perpendicular to the drive shaft axis; and
a pumping element associated with the cam follower (212; 312) and arranged to reduce the vol-

- ume of a pumping chamber during a forward stroke and to increase the volume of the pumping chamber during a reverse stroke; wherein the cam follower (212; 312) comprises first and second surfaces (216, 216a; 316, 316a) that cooperate with the rider (206; 306) at first and second sliding interfaces, respectively; and wherein the forward stroke of the pumping element is driven when the rider (206; 306) thrusts against the first surface (216; 316) during movement of the rider (206; 306) and the return stroke of the pumping element is driven when the rider (206; 306) thrusts against the second surface (216a; 316a) during movement of the rider (206; 306).
5. A pumping assembly according to Claim 3 or Claim 4, wherein the cam follower (212; 312) includes a first cross member (252; 352) comprising the first surface (216; 316) and a second cross member (252a; 352a) comprising the second surface (216a; 316a); and wherein the first and second cross members (252, 252a; 352, 352a) are disposed on opposite sides of the rider (206; 306).
 6. A pumping assembly according to Claim 5, wherein the cam follower (212; 312) includes at least one connecting member (254, 254a, 256, 256a; 354, 354a) that connects the first cross member (252; 352) to the second cross member (252a; 352a).
 7. A pumping assembly according to Claim 6, wherein the cam follower (212; 312) defines, at least in part, a volume (250; 350) for receiving the rider (206; 306) and the cam (204; 304).
 8. A pumping assembly according to Claim 7, wherein the cam follower (212; 312) comprises first and second connecting members (254, 254a, 256, 256a; 354, 354a) that connect respective ends of the first cross member (252; 352) to corresponding ends of the second cross member (252a; 352a), such that the first and second cross members (252, 252a; 352, 352a) and the first and second connecting members (254, 254a, 256, 256a; 354, 354a) define, at least in part, the volume (250; 350) for receiving the rider (206; 306) and the cam (204; 304).
 9. A pumping assembly according to any preceding Claim, wherein the sliding interface comprises at least one flattened region (110; 210; 310) of the rider (106; 206; 306) for cooperation with a surface (116; 216; 316) of the cam follower (112; 212; 312).
 10. A pumping assembly according to any preceding Claim, further comprising a housing (102; 202; 302) that receives the cam (104; 204; 304), the rider (106; 206; 306) and the cam follower (112; 212; 312).
 11. A pumping assembly according to Claim 10, wherein the housing (102; 202; 302) guides the cam follower (112; 212; 312) for reciprocal movement in a direction parallel to the cam follower axis (Q).
 12. A pumping assembly according to Claim 11, wherein the cam follower (212; 312) includes guide members (254, 254a; 354, 354a) arranged in sliding contact with a wall (262; 362) of the housing for guiding the reciprocal movement of the cam follower (212; 312).
 13. A pumping assembly according to any of Claims 10 to 12, wherein the cam follower (112; 212; 312) comprises a first drive member (158; 258; 358) for driving the pumping element, wherein the drive member (158; 258; 358) extends out of the housing (102; 202; 302).
 14. A pumping assembly according to Claim 13, wherein the cam follower (212; 312) further comprises a second drive member (258a; 358a) for driving a further pumping element, wherein the second drive member (258a; 358a) extends out of the housing (202; 302) in an opposite direction to the first drive member (258; 358).
 15. A pumping assembly according to any preceding Claim, comprising fluid flow means (268, 268a, 270, 270a, 272, 272a; 368, 368a, 370, 370a, 372, 372a) for permitting fluid flow through or past the rider (206; 306) and/or the cam follower (212; 312) during movement of the rider (206; 306) and/or the cam follower (212; 312).
 16. A pumping assembly according to Claim 15, wherein the fluid flow means comprises at least one fluid flow passage in the cam follower (212; 312).
 17. A high-pressure fuel pump for a fuel injection system, comprising:
 - a pumping assembly (100; 200; 300) according to any preceding Claim; and
 - a pump head including the pumping chamber.

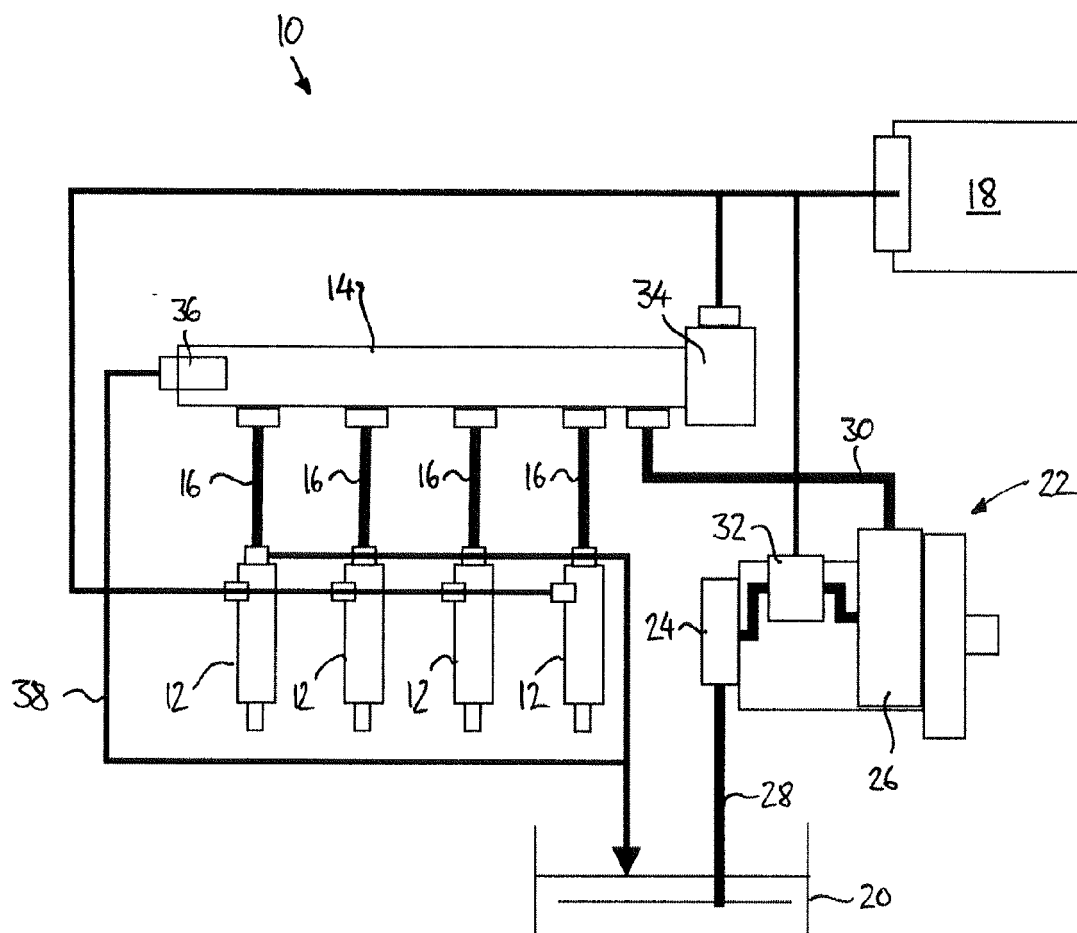


FIGURE 1

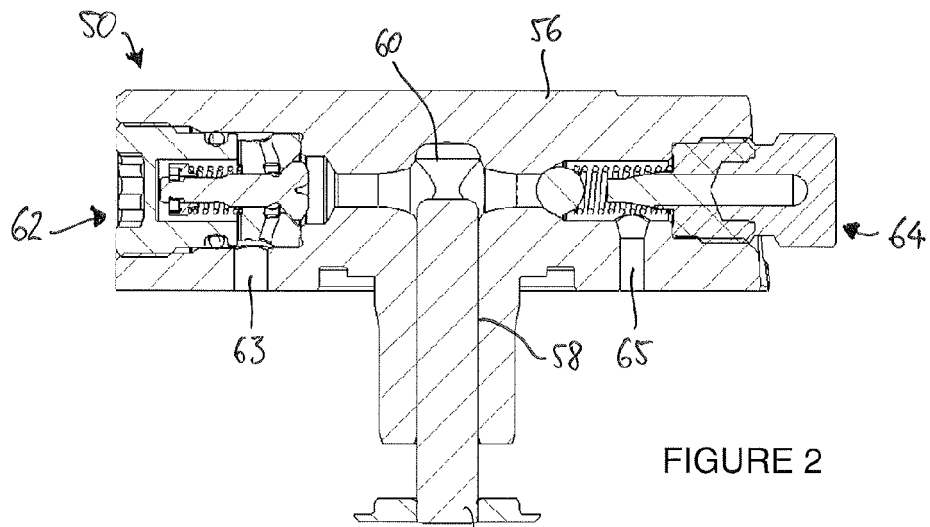


FIGURE 2

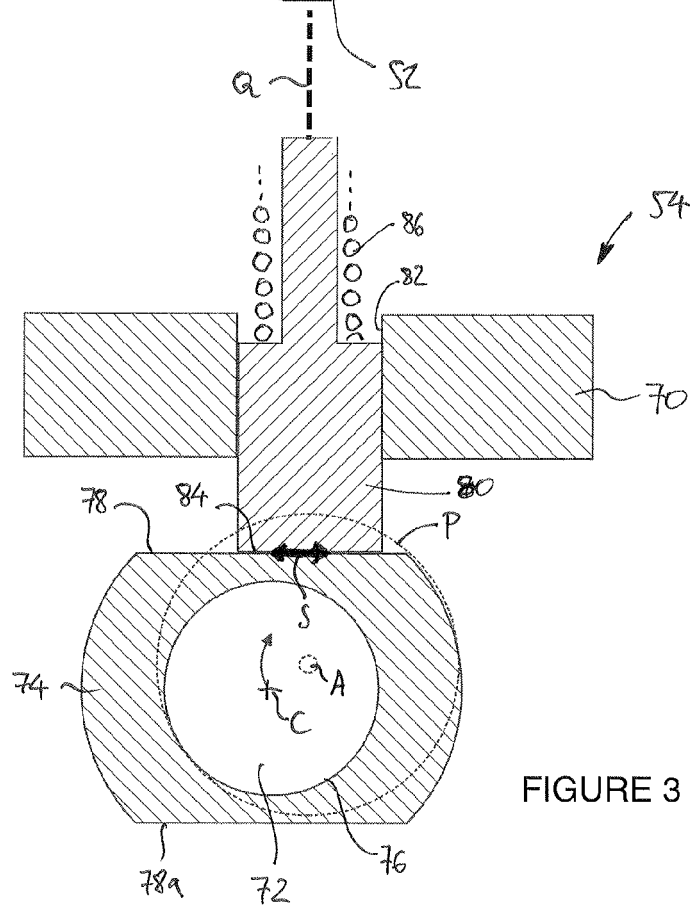


FIGURE 3

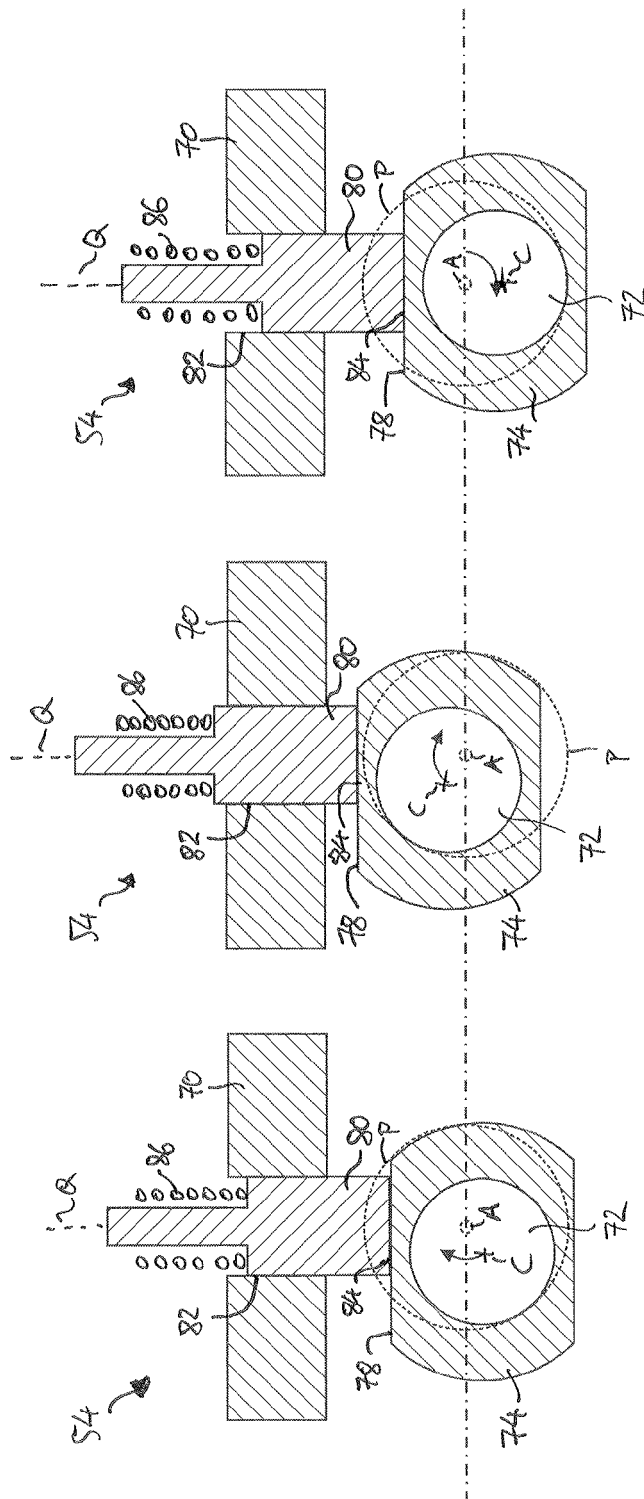


FIGURE 4(c)

FIGURE 4(b)

FIGURE 4(a)

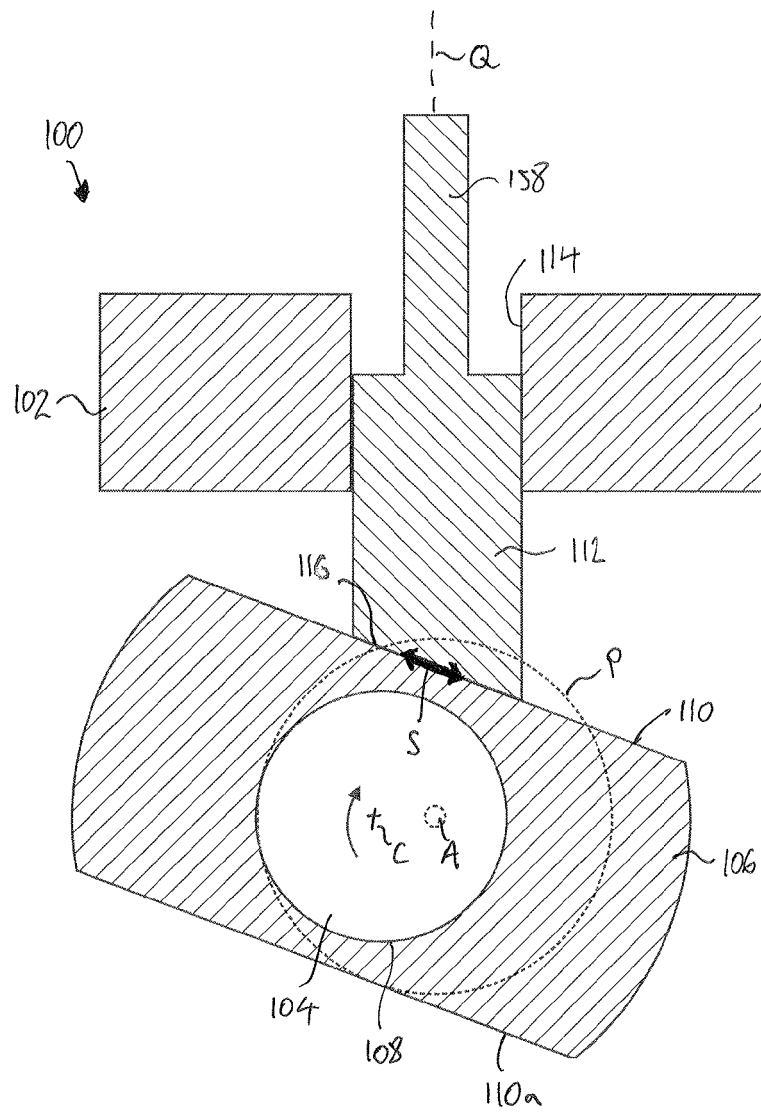


FIGURE 5

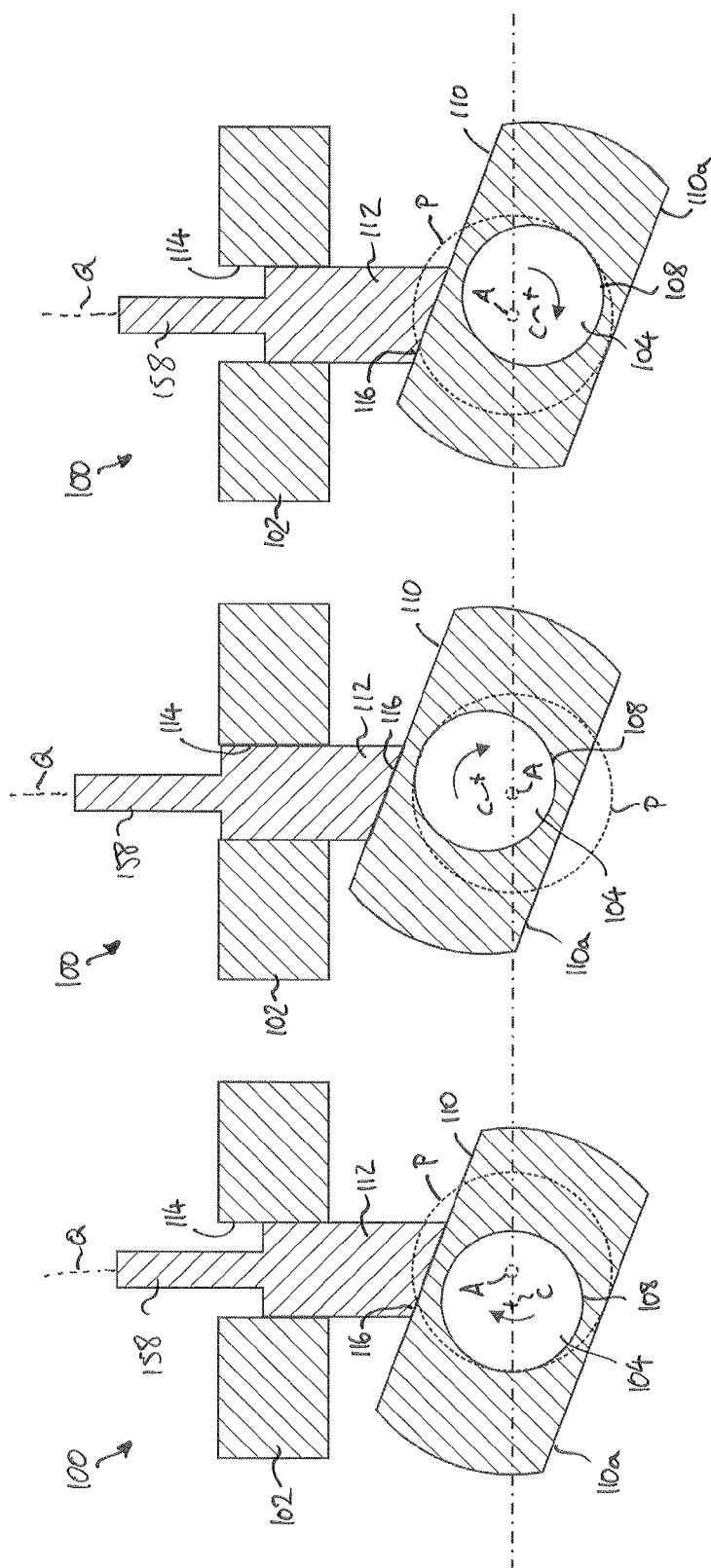


FIGURE 6(c)

FIGURE 6(b)

FIGURE 6(a)

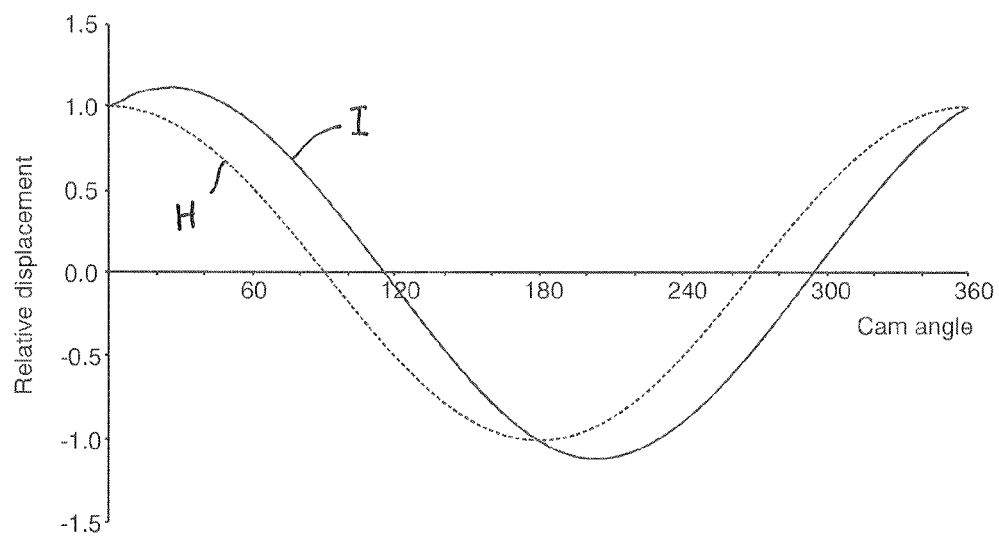


FIGURE 7

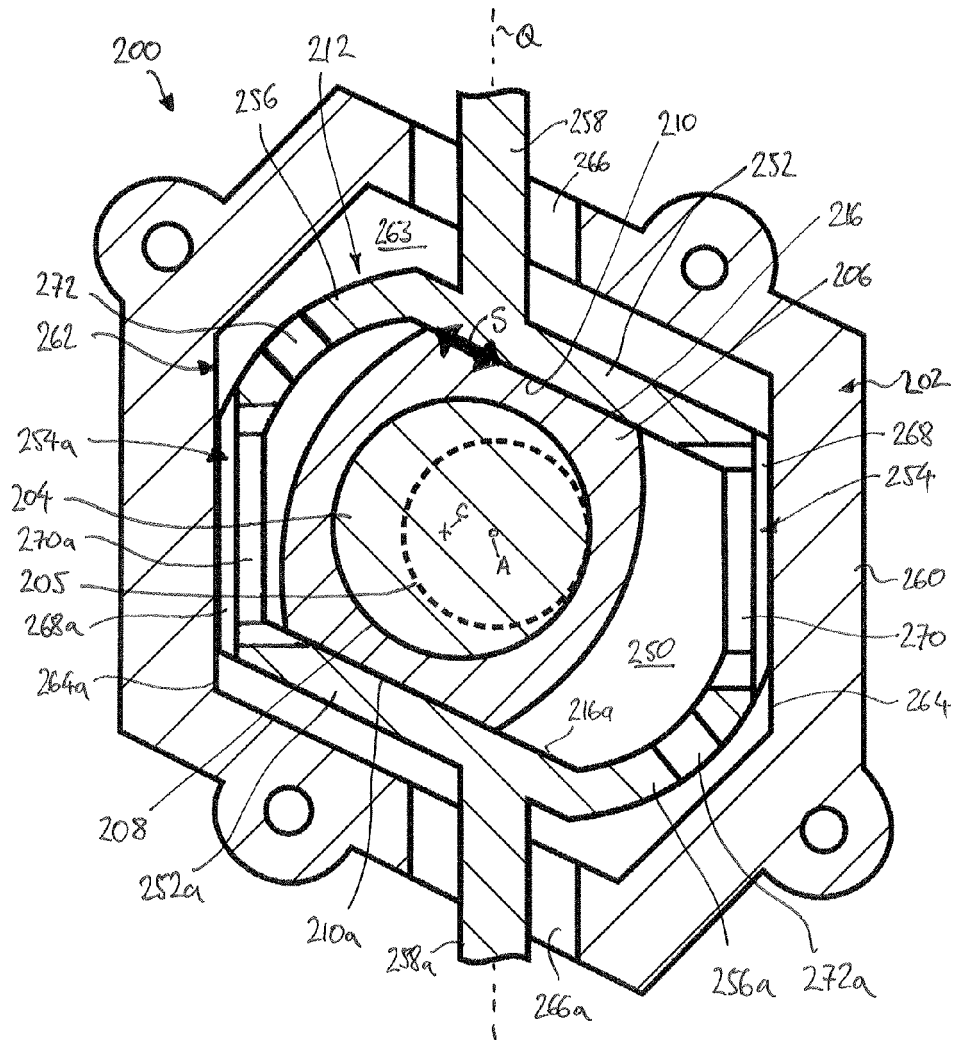


FIGURE 8

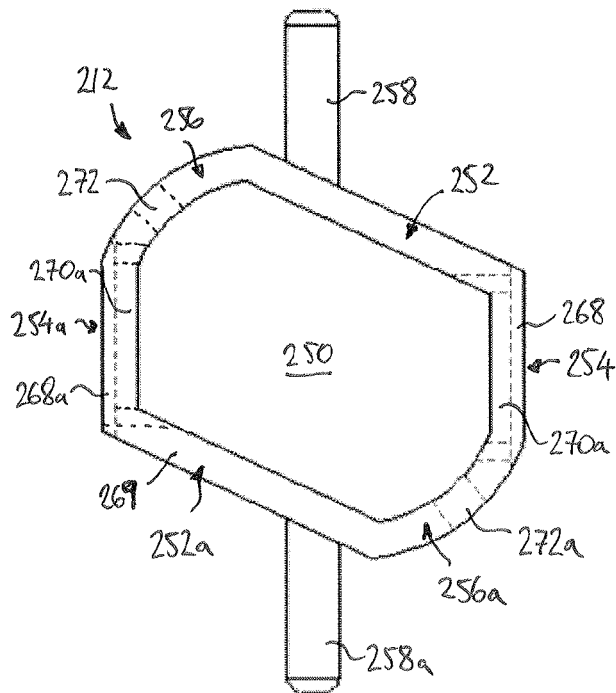


FIGURE 9(a)

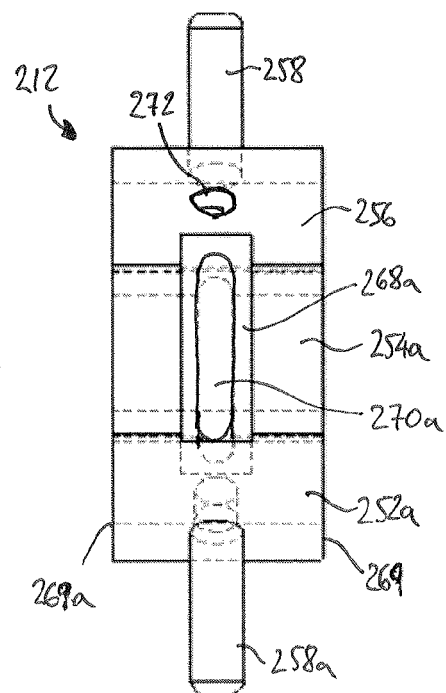


FIGURE 9(b)

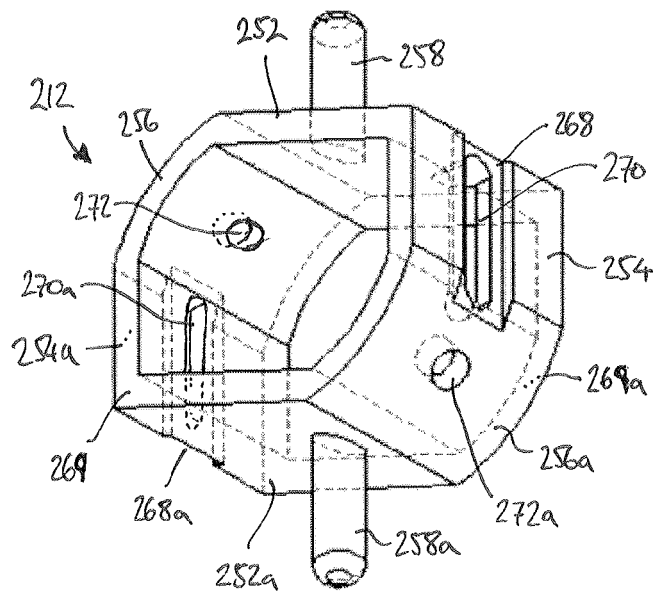
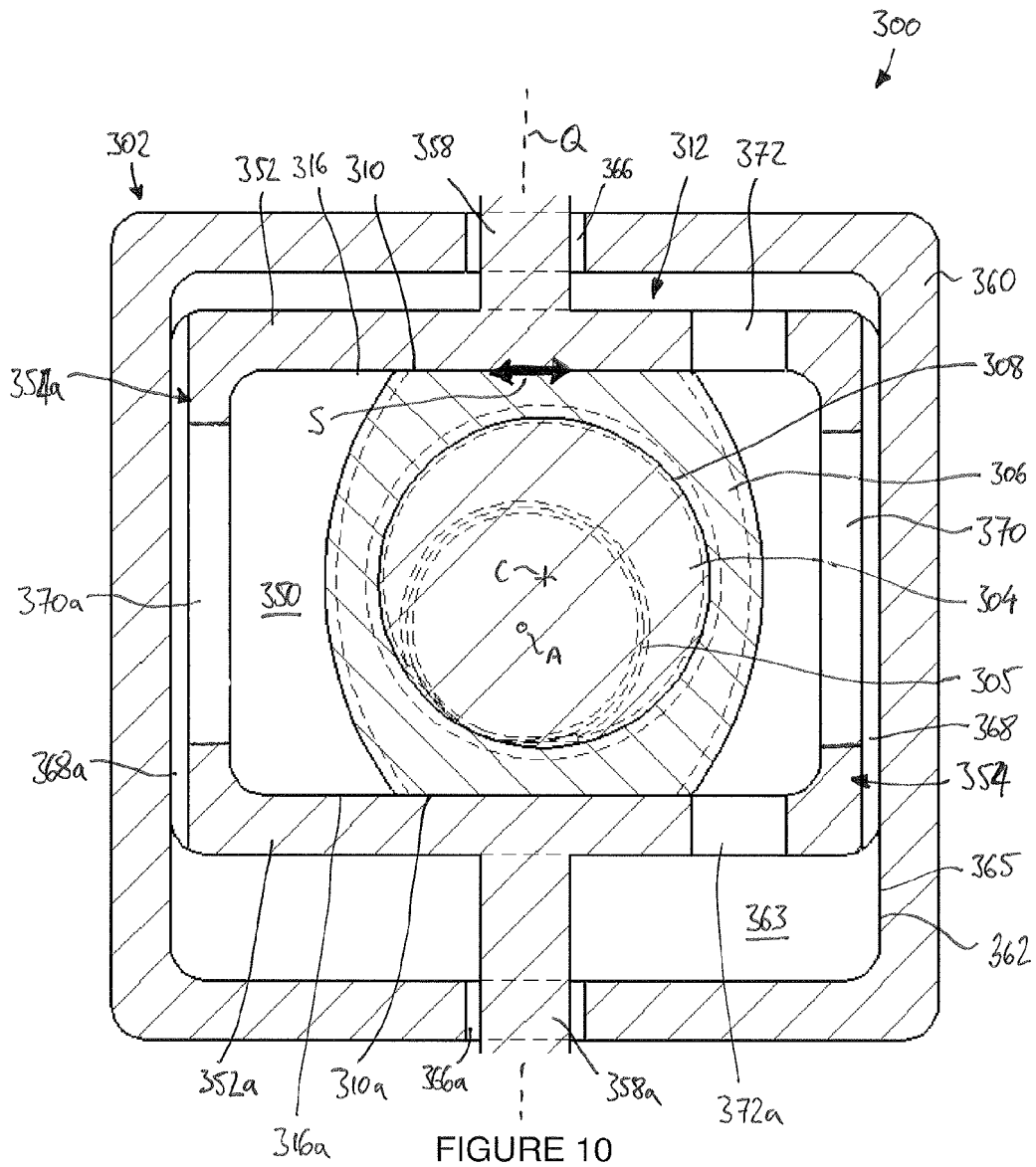


FIGURE 9(c)





EUROPEAN SEARCH REPORT

Application Number
EP 11 15 6272

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2008 002101 A1 (BOSCH GMBH ROBERT [DE]) 3 December 2009 (2009-12-03) * paragraph [0017]; figure 3 *	1,2	INV. F02M59/10 F04B9/04
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A	DE 10 2008 001718 A1 (BOSCH GMBH ROBERT [DE]) 19 November 2009 (2009-11-19) * abstract *	1-17	
A	DE 10 2009 014833 A1 (DAIMLER CHRYSLER AG [DE]) 30 September 2010 (2010-09-30) * abstract *	1-17	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC) F02M F04B
Place of search		Date of completion of the search	Examiner
The Hague		4 August 2011	Schmitter, Thierry
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 15 6272

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04-08-2011

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