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(71) Applicant *(for all designated States except US)*: **WOODWARD, INC.** [US/US]; 1000 E. Drake Road, P.O. Box 1519, Colorado 80525 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **WOOD, Mark Andrew** [GB/GB]; The Old Bakery, Two Mile Lane, Highnam Gloucestershire GL2 8DW (GB). **PARSONS, Antony Owen** [GB/GB]; 3, Gorse Hill, Ashton-Under-Hill, Evesham Worcestershire WR11 7SP (GB). **KAY, Andrew Swithin** [GB/GB]; 32, Alkerton Road, Eastington Gloucestershire GL10 3BJ (GB).

(74) Agent: **MAKEEVER, Jeffery J.**; REINHART BOERNER VAN DEUREN P.C., 2215 Perrygreen Way, Rockford, Illinois 61107 (US).

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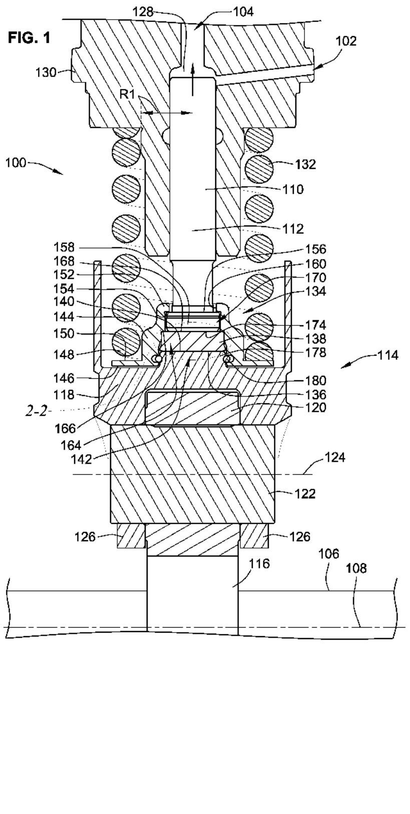
(54) Title: PUMP WITH CENTRALIZED SPRING FORCES

FIG. 1



(57) Abstract: A pump including a tappet biased into contact with a camshaft by a return spring is provided. The pump includes a torque transfer reduction interface mechanically interposed between the return spring and the tappet. The torque transfer reduction interface is configured to prevent spring wind-up generated by compressing and expanding the return spring from being transferred to the tappet to prevent the torque from causing the tappet to rotate relative to the camshaft about an axis extending perpendicular to the rotational axis of the camshaft.

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PUMP WITH CENTRALIZED SPRING FORCES

FIELD OF THE INVENTION

[0001] This invention generally relates to fluid pumping arrangements and more particularly to fluid pumping arrangements that include a return spring that maintains contact between a roller and tappet assembly that follows a camshaft to drive a plunger relative to a pumping barrel to pump the fluid.

BACKGROUND OF THE INVENTION

[0002] A common rail pump is used for pumping fluids and particularly fuel for engines. The pump includes a camshaft with roller tappets. The roller tappets are held against lobes of the camshaft to convert rotational motion of the camshaft into linear motion for lifting pumping plungers relative to a pumping barrel. The cyclical movement of the plungers in the pumping barrel pressurizes the fluid to pump the fluid.

[0003] Return springs are used to bias the roller tappets towards the camshaft. When the camshaft is rotated to a position where the a lobe of the camshaft has a small radius, the return spring pushes the roller tappet back to the starting position relative to the camshaft in preparation for the next rotation of the camshaft and pumping motion.

[0004] In some pumps, the return spring is a coil spring that extends around the plunger and between the pumping barrel and tappet. Unfortunately, when the coil spring is compressed and extended during the reciprocating pumping action, the ends of the coil spring try to rotate slightly which is known as spring wind-up. In many applications, this is not an issue or the spring ends will slide on the mating surface with limited kinetic frictional forces. However, if the ends of spring cannot adequately slide on the mating surfaces, a torque is imparted on the surfaces against which the ends of the coil spring press. This is problematic in the pumping environment.

[0005] In a pump, as the coil spring tries to rotate due to spring wind-up, the torque generated thereby is transferred to the roller tappet causing the roller tappet to rotate about the pumping axis along which the plunger reciprocates. This causes the roller to shift such that the rotational axis of the roller is no longer parallel to the rotational axis of the camshaft. With the axes angled relative to one another, the roller will not run on a true path on the camshaft. This causes the roller to move axially along the rotational axis within the tappet. The axial movement of the roller causes the axial end faces of the roller to rub axially against the end stop formed in the tappet generating undesirable wear.

[0006] The present invention relates to improvements over the art that substantially eliminates or reduces the transfer of the spring wind-up generated torque to the tappet.

BRIEF SUMMARY OF THE INVENTION

[0007] Embodiments of the present invention prevent spring wind-up of coil springs from imparting torque to a tappet of a pumping assembly that can cause mis-alignment of the tappet with a corresponding rotating cam.

[0008] In a particular embodiment, a pump including a tappet, a roller, a pumping barrel, a plunger, a return spring and torque transfer reduction interface is provided. The roller is rotatably carried by the tappet. The pumping barrel defines a pumping chamber. The plunger is slidably carried in the pumping chamber for motion along a pumping axis. The plunger is operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis. The return spring is operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel. The axial biasing forces of the return spring do not pass mechanically through the plunger to the tappet. The return spring is generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis. The torque transfer reduction interface is provided, at least in part, by first and second axially abutting surfaces that define a contact area therebetween when the return spring is in a state of compression. The torque transfer reduction interface is mechanically interposed between the return spring and the tappet such that the compressive forces generated by the return spring pass through the torque transfer reduction interface to the tappet. The contact area between the first and second surfaces has a maximum radial dimension relative to the pumping axis being less than the minimum radial dimension of the return spring.

[0009] In one embodiment, the torque transfer reduction interface is mechanically interposed between the return spring and the tappet such that an axial compressive force biasing the tappet away from the pumping barrel along the pumping axis is operably transmitted from the return spring to the tappet through the torque transfer reduction interface.

[0010] In one embodiment, at least one of the first and second surfaces is convex. In a more particular embodiment, the convex one of the first and second surfaces is generally spherically curved.

[0011] In one embodiment, the contact area of the torque transfer reduction interface is configured to permit angular slip between the first and second surfaces about a rotational axis generally parallel to the pumping axis when a maximum torque is generated on the return spring side of the torque transfer reduction interface. The maximum torque being a torque large enough to cause angular rotation of the tappet relative to the pumping barrel if the torque transfer reduction interface was not present.

[0012] A further embodiment includes a spring plate axially engaged by a distal end of the return spring that is free to rotate relative to the tappet about the pumping axis. The embodiment also includes a load button providing one of the first and second surfaces of the torque transfer reduction interface. The load button is mechanically interposed between the spring plate and the tappet such that axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression are operably transferred substantially entirely to the tappet through the load button.

[0013] In a more particular embodiment, the load button is free to angularly rotate about the pumping axis relative to the tappet.

[0014] In one embodiment, the return spring and the spring plate are not directly axially pressed against the tappet. This assists in reducing torque transfer between the tappet and either the return spring or the spring plate.

[0015] In one embodiment, the plunger has a plunger head and the spring plate includes a plunger head abutment flange surrounding a plunger receiving aperture. The plunger extends axially through the plunger receiving aperture with the plunger head axially interposed and trapped between the plunger head abutment flange and the load button.

[0016] In a more particular embodiment, the spring plate includes a radially outward extending spring abutment flange having a top surface facing the pumping barrel against which the distal end of the return spring is biased; a first bottom surface provided by the plunger head abutment flange facing axially away from the pumping barrel against which the plunger head abuts; and a second bottom surface facing axially away from the pumping barrel axially spaced from and between the first bottom surface and the top surface. The second bottom surface axially engages the load button.

[0017] In one embodiment, the spring plate is axially secured to the tappet and the return spring is a coil spring.

[0018] One embodiment further includes a plunger head cavity formed axially between the load button and the plunger head abutment flange in which the plunger head is received. The plunger head cavity has an axial dimension configured to provide limited axial movement of the plunger head axially between the plunger head abutment flange and the load button. When the return spring is being compressed, the plunger head will be biased against the load button and when the return spring is being expanded (i.e. lengthened), the plunger head will engage the plunger head abutment flange. This will prevent the plunger head from being clamped, and particularly axially clamped. Clamping the plunger head can undesirably prevent rotational motion of the plunger relative to the pumping axis as well as create potential binding problems of the plunger within the plunger barrel if there is slight mis-alignment in the systems. Further, the likelihood of loading the plunger in an unwanted sideways/radial direction, from small sideways movements of the tappet is reduced.

[0019] In one embodiment, the plunger head has an axial end surface facing axially away from the pumping barrel. The axial end surface of the plunger head axially biased against a top surface of the load button as the tappet travels towards the pumping barrel as the return spring is compressed. Preferably, at least one of the axial end surface of the plunger head and top surface of the load button being convex. The convex shape assists in centering the loading of the return spring.

[0020] In one embodiment, the maximum radial dimension of the contact area is less than twenty-five percent the minimum radial dimension of the return spring.

[0021] In one embodiment, the load button directly abuts an abutment surface of the tappet axially facing the pumping barrel. The torque transfer reduction interface is positioned axially closer to the pumping barrel than the distal end of the return spring. The abutment surface of the tappet is formed as a distal end of an axially extending land portion of the tappet. At least a portion of the spring plate surrounds at least a portion of the axially extending land portion.

[0022] A further embodiment of a pump includes a tappet, a roller, a pumping barrel, a plunger, a return spring, a spring plate, a load button, and a torque transfer reduction interface. The roller is rotatably carried by the tappet. The pumping barrel defines a pumping chamber. The plunger is slidably carried in the pumping chamber for motion along a pumping axis. The plunger is operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis. The plunger has a plunger head.

[0023] The return spring is operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel. The axial biasing forces of the return spring do not pass mechanically through the plunger to the tappet. The return spring is generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis.

[0024] The spring plate is axially operably engaged by a distal end of the return spring. The plunger extends through a plunger aperture in the spring plate with the plunger head axially interposed between the tappet and the spring plate. The plunger head is larger than the plunger aperture. The spring plate being mechanically operably fixed to the tappet for substantially coordinated axial movement with the tappet in cyclical opposite directions along the pumping axis.

[0025] The load button is axially interposed between the tappet and the plunger head. The load button is mechanically interposed between the spring plate and the tappet such that the portion of the axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression that are operably transferred to the tappet are transferred substantially entirely to the tappet through the load button.

[0026] The torque transfer reduction interface is provided, at least in part, by first and second surfaces axially abutting and defining a contact area therebetween when the return spring is in a state of compression. The torque transfer reduction interface is mechanically interposed between the return spring and the tappet. The contact area between the first and second surfaces has a maximum radial dimension relative to the pumping axis being less than the minimum radial dimension of the return spring. The load button provides one of the first and second surfaces of the torque transfer reduction interface.

[0027] In one embodiment, the spring plate includes a plunger head abutment flange surrounding the plunger aperture. The plunger aperture may be sized such that the plunger is not tightly located/clamped radially by the spring plate or tappet. The plunger head is axially interposed and trapped between the plunger head abutment flange and the load button. A plunger head cavity is formed axially between the load button and the plunger head abutment flange in which the plunger head is received. The plunger head cavity has an axial dimension slightly larger than the axial dimension of the plunger head such that the plunger head cavity is configured to provide limited axial movement of the plunger head axially between the plunger head abutment flange and the load button. This sizing prevents axially clamping the plunger head. The plunger head has an axial end surface facing axially away from the pumping barrel. The axial end surface of the plunger head is axially biased against a top surface of the load button as the tappet travels towards the pumping barrel as the return spring is compressed. At least one of the axial end surface of the plunger head and top surface of the load button are convex. The plunger head is axially biased against the plunger head abutment flange when the tappet travels away from the pumping barrel along the pumping axis. By preventing axially or radially clamping/tightly locating the plunger, and particularly the plunger head, the likelihood of loading the plunger in an unwanted sideways/radial direction, from small sideways movements of the tappet is reduced.

[0028] In a further embodiment, a pump including a rotating cam shaft, a tappet, a roller, a pumping barrel, a plunger, a return spring, and a torque transfer reduction interface is provided.

[0029] The rotating camshaft is configured for rotation about a camshaft rotational axis including at least one cam lobe.

[0030] The roller is carried for rotation by the tappet and follows the cam lobe. The tappet and roller convert rotational motion of the camshaft about the camshaft rotational axis into linear displacement of the tappet along a pumping axis.

[0031] The pumping barrel defines a pumping chamber. The plunger is slidably carried in the pumping chamber for motion along the pumping axis due to rotation of the camshaft. The plunger is operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis.

[0032] The return spring is operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel. The axial biasing forces of the return spring do not pass mechanically through the plunger to the tappet.

[0033] The torque transfer reduction interface is provided, at least in part, by first and second surfaces axially abutting and defining a contact area therebetween when the return spring is in a state of compression. The torque transfer reduction interface mechanically interposed between the return spring and the tappet. The contact area of the torque transfer reduction interface being configured to permit angular slip between the first and second surfaces about a rotational axis generally parallel to the pumping axis when a minimum torque is present on the return spring side of the torque transfer reduction interface rather than to transfer the minimum torque to the tappet to cause the tappet to rotate about an axis generally parallel to the pumping axis relative to the camshaft.

[0034] In a more particular embodiment, the return spring is generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis and the contact area between the first and second surfaces has a maximum radial dimension relative to the pumping axis that is less than the minimum radial dimension of the return spring.

[0035] In one embodiment, the minimum torque is a torque at least large enough to cause angular rotation of the tappet relative to the camshaft about an axis generally perpendicular to the rotational axis of the camshaft.

[0036] In one embodiment, the torque transfer reduction interface is mechanically interposed between the return spring and the tappet such that an axial compressive force biasing the tappet away from the pumping barrel and towards the camshaft along the pumping axis is operably transmitted from the return spring to the tappet through the torque transfer reduction interface.

[0037] In one embodiment, at least one of the first and second surfaces is convex. In one embodiment, the convex one of the first and second surfaces is generally spherically curved.

[0038] In one embodiment, a spring plate is axially engaged by a distal end of the return spring. Further, a load button provides one of the first and second surfaces of the torque transfer reduction interface. The load button is mechanically interposed between the spring plate and the tappet such that axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression that are operably transferred to the tappet are transferred substantially entirely to the tappet through the load button.

[0039] Other aspects, objectives and advantages of the invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

[0041] FIG. 1 is a partial cross-sectional illustration of pumping arrangement according to an embodiment of the present invention; and

[0042] FIG. 2 is an enlarged partial cross-sectional illustration of the torque transfer reduction interface of the pump of FIG. 1.

[0043] While the invention will be described in connection with certain preferred embodiments, there is no intent to limit it to those embodiments. On the contrary, the intent is to cover all alternatives, modifications and equivalents as included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0044] FIG. 1 is a simplified partial cross-sectional illustration of a pump 100 according to an embodiment of the present invention. The pump 100 is used for pumping fluid by pressurizing the fluid. The pump 100 includes an inlet port 102 and an outlet port 104. Fluid enters through the inlet port 102 is pressurized and then pumped out of outlet port 104.

[0045] To perform the pumping operations, the pump includes a camshaft 106 that rotates about a camshaft axis 108 to drive a plunger 110 in reciprocating motion along a pumping axis 112. The reciprocating motion of the plunger 110 causes the fluid to be pressurized and pumped through the pump 100.

[0046] The pump 100 includes a roller tappet arrangement 114 that cooperates with a variable radius lobe 116 of camshaft 106 to transform the rotational motion of the camshaft 106 into the linear motion required for the pumping action.

[0047] The roller tappet arrangement 114 generally includes a tappet 118 that rotatably carries a roller 120. The roller 120 is secured on a roller pin 122 for rotation about pin axis 124 relative to tappet 118. The pin axis 124 is substantially perfectly parallel to camshaft axis 108 during normal operation. As such, lateral forces parallel to axes 124, 108 are not imparted on the roller 120 due to the interaction of the roller 120 with camshaft 106. As such, the axial end faces of the roller 120 are not biased into the axial stops 126 of the tappet 118 that support the roller pin 122.

[0048] The plunger 110 is slidably carried in a pumping chamber 128 formed in a pumping barrel 130 of the pump 100. The pumping chamber 128 is in fluid communication with the inlet port 102 and outlet port 104 such that axial motion of the plunger 110 within the pumping chamber 128 operably causes fluid to be pressurized and pumped out of the outlet port 104.

[0049] The plunger 110 is operably coupled to the tappet 118 for substantially coordinated movement with the tappet 118 along the pumping axis 112. As such, when the camshaft 106 rotates and forces the tappet 118 axially along the pumping axis 112 towards the pumping barrel 130, the plunger 110 travels along with the tappet 118 in substantially the same amount of displacement and in substantially the same direction.

[0050] A return spring 132 (also referred to herein as "coil spring 132") is operably positioned between the pumping barrel 130 and the tappet 118 to axially bias the tappet 118 away from the pumping barrel 130. The biasing forces generated by the return spring 132 when it is compressed are used to return the tappet 118 towards a starting position relative to the camshaft 106. The starting position of the camshaft 106 is the location where the lobe 116 has its smallest radius. In other words, the return spring 132 forces the tappet 118 towards camshaft 106 to maintain radial abutment contact between the outer surface of the roller 120 and the outer surface of the lobe 116.

[0051] Preferably, the operable coupling of the plunger 110 to the tappet 118 is such that the axial biasing forces of the return spring 132 do not pass mechanically through the plunger 110 to the tappet 118. In other words, the axial biasing forces generated when the compression spring 132 is compressed that force the tappet 118 away from the pumping barrel 130 are not translated through the plunger 110 as they are transferred to the tappet 118 to maintain roller 120 in contact with the camshaft 106.

[0052] The return spring 132 in the illustrated embodiment is a generally tubular coil spring. The tubular coil spring is generally centered on the pumping axis 112.

[0053] As noted in the Background, when coil springs such as that used in the instant invention compress and expand the ends of the coil will want to extend or shorten. This motion of the spring can impart a torque to the surfaces upon which the spring is acting. Therefore, it can be detrimental if this force is applied to the tappet 118 as it can create a torque within the tappet 118 about an axis that is generally parallel to the pumping axis 112. Such a torque can cause angular rotation of the tappet 118 relative to the camshaft 106 about the pumping axis 112 or an axis parallel thereto such that the pin axis 124 and the camshaft axis 108 are no longer substantially parallel to one another. This arrangement, again, can cause the roller 120 to be subject to axial forces along the pin axis 124 such that the end faces of the roller 120 are axially forced into the axial stops 126 causing significant friction and wearing of the end faces of the roller 120.

[0054] The pump 100 of the illustrated embodiment of FIG. 1 includes a torque transfer reduction interface 134 that substantially reduces the ability for torques generated due to this feature of a coil spring, noted above as spring wind-up, to be transferred to the tappet 118. The torque transfer reduction interface 134 is configured to allow operably relative movement between the coil spring 132 and the tappet 118 due to the spring wind-up. As such any torques that are generated do not cause the tappet 118 to rotate such that the pin axis 124 loses its parallelism with the camshaft axis 108.

[0055] The torque transfer reduction interface 134 of the illustrated embodiment is provided, at least in part, by a bottom surface 136 of a load button 138 and a top surface 140 of a portion of the tappet 118. These surfaces 136, 140 axially abut defining a contact area 142 therebetween when the return spring 132 is in a state of compression. This torque transfer reduction interface 134 is operably mechanically interposed between the return spring 132 and the tappet 118. As such, the axial compression forces of the return spring 132 are axially transferred operably from the return spring 132 to the tappet 118 through this contact area (generally illustrated at arrow 142).

[0056] The use of this torque transfer reduction interface 134 changes the mode at which the force generated due to the spring wind-up of the return spring 132 is handled relative to tappet 118. First, any torque that is applied to the tappet 118 from the spring wind-up is transferred to the tappet 118 at a significantly reduced radius as compared to if the distal end 148 of the return spring 132 were to act directly on a surface of the tappet

118. Some prior art embodiments utilize a spring plate that is interposed between the coil spring and the tappet that engages a head portion of the plunger (see e.g. spring plate 144 which is not a prior art spring plate but illustrates the interaction). However, in the prior art embodiments, a radially outward extending spring abutment flange, which the end of the return spring is biased, (see e.g. flange 146 of the instant embodiment, which is not constructed like the prior art) would be directly axially compressed against the tappet (unlike flange 146 of the instant embodiment which is axially spaced therefrom). In such a configuration, the spring wind-up would act through the spring plate substantially at a same radius as if the return spring were to act directly on the tappet.

[0057] Another prior art design, presses on the spring plate which presses on the plunger head and presses the plunger head directly into contact with the tappet. The plunger head is thus axially clamped tightly against the tappet in this arrangement. This tight clamping of the plunger relative to the tappet can result in undesirably loading the plunger in an unwanted sideways/radial direction from small sideways movements of the tappet.

[0058] Further, the torque transfer reduction interface 134, and particularly the contact area 142 thereof, is configured to reduce the surface area through which torque could be transferred to the tappet 118. By reducing size and the maximum radius of contact area 142 relative to the pumping axis 112, the torque transfer reduction interface 134 begins to approximate a point contact. As such, the rotational frictional engagement between the two surfaces 136, 140 is overcome by very minimal torques. As such, when torques are generated due to the forces caused by spring wind-up of the return spring 132 the two surfaces 136, 140 are allowed to angularly rotate relative to one another along the pumping axis 112 rather than to result in a transfer of torque to the tappet 118.

[0059] Further, it is preferable that the contact area 142 between the two surfaces 136, 140 and particularly the radius thereof transitions towards or near a radius of zero. As such, the rotational frictional forces that are generated and act normal to surfaces 136, 140 act through a torque arm that is substantially zero. This significantly reduces the amount of torque that is transferred to the tappet 118 as the torque is proportional to the torque arm at which the frictional forces are applied.

[0060] With additional reference to FIG. 2, which is an enlarged illustration of the torque transfer reduction interface 134, the bottom surface 136 of the load button 138 is generally spherically curved. The top surface 140 of tappet 118 forming the other portion of the torque transfer reduction interface 134 is substantially planer. As such, the contact area 142 between these two surfaces 136, 140 when they axially abut approximates a point contact. However, due to some deformation the contact area 142 is slightly larger than a point contact. This as noted above drives radius of the contact area 142 near zero. The spherically curved surface profile of the bottom surface 136 also ensures central loading.

[0061] While the bottom surface 136 is illustrated as being spherically curved, the top surface 140 in alternative embodiments could additionally or alternatively be the spherically curved surface. Further, alternative embodiments may use surfaces other than spherically curved surfaces. For instance, the surfaces could be generally conical or frustoconical with only a small portion of the tip of the cone removed. Again, the goal is to reduce the contact area and particularly the maximum radial dimension thereof.

[0062] As noted above, the torque transfer reduction interface 134 significantly reduces the torque arm through which any forces generated due to the spring wind-up are transferred to the tappet 118. For instance, in prior art designs where the coil spring was directly biased against the tappet, the torque arm was at least as great as the inner radius R1 of the coil spring 132 relative to the pumping axis 112, which may also be referred to as the minimum radial dimension of the inner periphery of the coil spring. Similarly, in embodiments that had the radially outward extending spring abutment flange directly compressed the tappet, the torque arm was at least as great as the inner radius of the portion of the radially outward extending spring abutment flange that axially abutted the tappet relative to the pumping axis thereof. However, the new torque arm using the torque transfer reduction interface 134 is at most the maximum radial dimension of the contact area 142. This maximum radial dimension is significantly less than the minimum radial dimension R1 of the return spring 132 and as noted above is near zero.

[0063] The interface between the load button 138 and the tappet 118 is such that the load button is free to angularly rotate about the pumping axis 112 relative to the tappet 118. In other words, the only resistance to rotation between the two components is the frictional forces generated therebetween.

[0064] The contact area 142 of the torque transfer reduction interface 134 is configured such that the two surfaces are permitted to angularly slip about the pumping axis 112 when a maximum torque is generated by the return spring side of the torque transfer reduction interface. The maximum torque is a torque that is large enough to otherwise cause angular rotation of the tappet 118 relative to the pumping barrel 130 if the torque transfer reduction interface 134 was not present. In other words, the maximum torque would be a torque that would be sufficient to cause the tappet 118 to overcome the internal forces between the camshaft 106 and the tappet arrangement 114 to cause the tappet 118 to rotate relative to the camshaft 106.

[0065] In one embodiment, the maximum dimension of the contact area 142 is less than seventy-five percent the minimum radius R1, more preferably less than fifty percent, more preferably less than twenty-five percent.

[0066] A spring plate 144 is mechanically interposed between the return spring 132 and the tappet 118. The spring plate 144 mechanically acts on the load button 138 to transfer the axial compressive forces of the return spring 132 to the load button 138, which can then be transferred to tappet 118 via the torque transfer reduction interface 134.

[0067] The spring plate 144 includes an annular radially outward extending spring abutment flange 146 that is axially engaged by a distal end 148 of the return spring 132. The return spring 132 acts on a top surface 150 of the radially outward extending spring abutment flange 146 that axially faces the pumping barrel 130.

[0068] The spring plate 144 further includes an annular plunger head abutment flange 152 that includes a bottom surface 154 that axially abuts a top surface 156 of a plunger head 158 of plunger 110. The spring plate 144 defines a plunger receiving aperture 160 through which the plunger 140 extends. The plunger receiving aperture 160 is radially bounded by the plunger head abutment flange 152. The plunger head 158 is dimensioned such that it is larger than the plunger receiving aperture 160 such that the plunger head 158 cannot pass through the plunger receiving aperture 160. As such, when the coil spring axially biases the spring plate 144 away from the pumping barrel 130 such that it travels away from pumping barrel 130 the plunger 110 travels in coordinated axial movement with the spring plate 144 along pumping axis 112. Preferably, the plunger aperture 160 is sized to prevent tightly radially locating the plunger 110 therein.

[0069] The spring plate 144 includes a stepped region 164 that defines a further bottom annular surface 166 that axially abuts a top surface 168 of the load button 138. This axial abutment between the spring plate 144 and the load button 138 allows the axial forces of the return spring 132 to be transferred to the load button 138 through the spring plate 144. The forces are then operably transferred to the tappet 118 from the load button. Similarly, the axial forces generated by the displacement of the tappet 118 due to rotation of the camshaft

106 and its corresponding lobe 116 are transferred from the tappet 118 to the load button 138 and then subsequently transferred to the spring plate 144 to compress return spring 132.

[0070] The stepped region 164, and particularly the bottom surface 166 thereof axially faces away from the pumping barrel. In the illustrated embodiment, the bottom surface 166 that engages the load button 138 is axially interposed between radially outward extending spring abutment flange 146 and the radially inward extending plunger head abutment flange 152. This recessed arrangement allows for a longer return spring 132 while still providing room for the load button 138.

[0071] The plunger head 158 is axially secured within a plunger head cavity 170 formed axially between the load button 138 and the plunger head abutment flange 152. Preferably, the plunger head cavity has an axial dimension relative to the pumping axis 112 that is configured to provide limited axial movement of the plunger head 158 axially between the plunger head abutment flange 152 and the load button 138.

[0072] Due to the particular arrangement of the spring plate 144 relative to the load button 138 and tappet 118, no axial compressive forces that are used to bias the tappet 118 away from the pumping barrel 130 are transferred to the tappet operably through the plunger 110. This is particularly true in the fact that the plunger head 158 is axially dimensioned smaller than the axial dimension of the plunger head cavity 170 to permit limited axial displacement between the load button 138 and the plunger head abutment flange 152.

[0073] When the camshaft 106 causes the tappet arrangement 114 to drive the plunger 110 upward and cause a pumping action, the force transferred to the plunger 110 is transferred through the load button 138. In a preferred embodiment the bottom surface 174 of the plunger head 158 is spherically curved and the top surface 168 of the load button 138 is substantially planer. Again, this relationship provides substantially a point contact between the two contacting surfaces 168, 174. This arrangement allows for centrally loading the plunger 110 as the tappet 118 travels towards the pumping barrel. It should be noted, that these spherically curved surfaces 174 and 136 are convex surfaces. This arrangement allows for the point contact with the mating surfaces.

[0074] Other than frictional forces, the spring plate 144, plunger 110, tappet 118, and load button 138 are free to rotate relative to one another relative to the pumping axis 112 or axes parallel thereto in an entire 360° range. As such, no mechanical structures, other than friction, transfer torque from the spring plate 144 to the tappet 118 or limit relative angular motion between the spring plate and the tappet.

[0075] In the illustrated embodiment, the top surface 140 of the tappet 118 against which the load button 138 axially abuts is formed on an axially extending land portion 178 of the tappet 118. The radially outward extending spring abutment flange 146 is radially spaced outward from and surrounds a portion of the axially extending land portion 178. As such, the torque transfer reduction interface is axially interposed between the distal end 148 of the return spring 132 and the pumping barrel 130.

[0076] The spring plate 144 is axially secured to the tappet 118 by a retaining ring 180 that is radially inserted into radially directed annular grooves of the spring plate 144 and the land portion 178 of the tappet 118. This configuration causes the spring plate 144 to move in substantially coordinated axial motion with the tappet 118. However, the configuration is such that substantially none, if not any of the axial forces transferred between the tappet 118 and the return spring 132 are transferred through the retaining ring 180. The retaining ring 180 significantly assists in assembly of the system by securing the spring plate 144 to the tappet 118 and thereby secures the tappet 118, load button 138, spring plate 144, and plunger 110 into an interconnected unit. The retaining ring 180 also is loosely fit in the grooves of land portion 178 and the spring plate 144 such that no angular torques are transferred through the retaining ring 180.

[0077] In the illustrated embodiment, neither the spring plate 144 nor the return spring 132 directly press axially against the tappet 118. This configuration directs the axial compression forces of the return spring 132 that are applied to the tappet 118 through the torque transfer reduction interface 134 rather than directly from the return spring 132 or the annular radially outward extending spring abutment flange 146.

[0078] All references, including publications, patent applications, and patents cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0079] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) is to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0080] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

WHAT IS CLAIMED IS:

1. A pump comprising:

a tappet;

a roller rotatably carried by the tappet;

a pumping barrel defining a pumping chamber;

a plunger slidably carried in the pumping chamber for motion along a pumping axis, the plunger operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis;

a return spring operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel, the axial biasing forces of the return spring not passing mechanically through the plunger to the tappet, the return spring being generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis; and

a torque transfer reduction interface provided, at least in part, by first and second surfaces axially abutting and defining a contact area therebetween when the return spring is in a state of compression, the torque transfer reduction interface being mechanically interposed between the return spring and the tappet, the contact area between the first and second surfaces having a maximum radial dimension relative to the pumping axis being less than the minimum radial dimension of the return spring.

2. The pump of claim 1, wherein the torque transfer reduction interface is mechanically interposed between the return spring and the tappet such that an axial compressive force biasing the tappet away from the pumping barrel along the pumping axis is operably transmitted from the return spring to the tappet through the torque transfer reduction interface.

3. The pump of claim 1, wherein at least one of the first and second surfaces is convex.

4. The pump of claim 3, wherein the convex one of the first and second surfaces is generally spherically curved.

5. The pump of claim 1, wherein the contact area of the torque transfer reduction interface is configured to permit angular slip between the first and second surfaces about a rotational axis generally parallel to the pumping axis when a maximum torque is generated on the return spring side of the torque transfer reduction interface, the maximum

torque being a torque large enough to cause angular rotation of the tappet relative to the pumping barrel if the torque transfer reduction interface was not present.

6. The pump of claim 1, further comprising:

a spring plate axially engaged by a distal end of the return spring that is free to rotate relative to the tappet about the pumping axis;

a load button providing one of the first and second surfaces of the torque transfer reduction interface, the load button being mechanically interposed between the spring plate and the tappet such that axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression are operably transferred substantially entirely to the tappet through the load button.

7. The pump of claim 6, wherein the load button is free to angularly rotate about the pumping axis relative to the tappet.

8. The pump of claim 6, wherein the return spring and the spring plate are not directly axially pressed against the tappet.

9. The pump of claim 6, wherein the plunger has a plunger head and the spring plate includes a plunger head abutment flange surrounding a plunger receiving aperture, the plunger extending axially through the plunger receiving aperture with the plunger head axially interposed and trapped between the plunger head abutment flange and the load button.

10. The pump of claim 9, wherein the spring plate includes:

a radially outward extending spring abutment flange having a top surface facing the pumping barrel against which the distal end of the return spring is biased;

a first bottom surface provided by the plunger head abutment flange facing axially away from the pumping barrel against which the plunger head abuts; and

a second bottom surface facing axially away from the pumping barrel axially spaced from and between the first bottom surface and the top surface, the second bottom surface axially engaging the load button.

11. The pump of claim 10, wherein the spring plate is axially secured to the tappet and the return spring is a coil spring.

12. The pump of claim 10, further comprising a plunger head cavity formed axially between the load button and the plunger head abutment flange in which the plunger head is received, the plunger head cavity having an axial dimension configured to provide limited axial movement of the plunger head axially between the plunger head abutment flange and the load button.

13. The pump of claim 12, wherein the plunger head has an axial end surface facing axially away from the pumping barrel, the axial end surface of the plunger head axially biased against a top surface of the load button as the tappet travels towards the pumping barrel as the return spring is compressed, at least one of the axial end surface of the plunger head and top surface of the load button being convex.

14. The pump of claim 1, wherein the maximum radial dimension of the contact area is less than twenty-five percent the minimum radial dimension of the return spring.

15. The pump of claim 6, wherein the load button directly abuts an abutment surface of the tappet axially facing the pumping barrel, the torque transfer reduction interface being positioned axially closer to the pumping barrel than the distal end of the return spring, the abutment surface of the tappet being formed as a distal end of an axially extending land, at least a portion of the spring plate surrounding at least a portion of the axially extending land.

16. A pump comprising:

a tappet;

a roller rotatably carried by the tappet;

a pumping barrel defining a pumping chamber;

a plunger slidably carried in the pumping chamber for motion along a pumping axis, the plunger operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis, the plunger having a plunger head;

a return spring operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel, the axial biasing forces of the return spring not passing mechanically through the plunger to the tappet, the return spring being generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis; and

a spring plate axially engaged by a distal end of the return spring, the plunger extending through a plunger aperture in the spring plate with the plunger head axially interposed between the tappet and the spring plate, the plunger head being larger than the plunger aperture, the spring plate being mechanically fixed to the tappet for substantially coordinated axial movement with the tappet in opposite directions along the pumping axis;

a load button axially interposed between the tappet and the plunger head, the load button being mechanically interposed between the spring plate and the tappet such that axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression are operably transferred substantially entirely to the tappet through the load button; and

a torque transfer reduction interface provided, at least in part, by first and second surfaces axially abutting and defining a contact area therebetween when the return spring is in a state of compression, the torque transfer reduction interface mechanically interposed between the return spring and the tappet, the contact area between the first and second surfaces having a maximum radial dimension relative to the pumping axis being less than the minimum radial dimension of the return spring, the load button providing one of the first and second surfaces of the torque transfer reduction interface.

17. The pump of claim 16, wherein the spring plate includes a plunger head abutment flange surrounding the plunger aperture, plunger head axially interposed and trapped between the plunger head abutment flange and the load button; and

a plunger head cavity is formed axially between the load button and the plunger head abutment flange in which the plunger head is received, the plunger head cavity having an axial dimension configured to provide limited axial movement of the plunger head axially between the plunger head abutment flange and the load button; and

wherein the plunger head has an axial end surface facing axially away from the pumping barrel, the axial end surface of the plunger head axially biased against a top surface of the load button as the tappet travels towards the pumping barrel as the return spring is compressed, at least one of the axial end surface of the plunger head and top surface of the load button being convex; and

wherein the plunger head is axially biased against the plunger head abutment flange when the tappet travels away from the pumping barrel along the pumping axis.

18. A pump comprising:

a rotating camshaft configured for rotation about a camshaft rotational axis including at least one cam lobe;

a tappet;

a roller carried for rotation by the tappet and following the cam lobe, the tappet and roller converting rotational motion of the camshaft about the camshaft rotational axis into linear displacement of the tappet along a pumping axis;

a pumping barrel defining a pumping chamber;

a plunger slidably carried in the pumping chamber for motion along the pumping axis due to rotation of the camshaft, the plunger operably coupled to the tappet for substantially coordinated movement with the tappet along the pumping axis;

a return spring operably positioned between the pumping barrel and the tappet to axially bias the tappet away from the pumping barrel, the axial biasing forces of the return spring not passing mechanically through the plunger to the tappet, and

a torque transfer reduction interface provided, at least in part, by first and second surfaces axially abutting and defining a contact area therebetween when the return spring is in a state of compression, the torque transfer reduction interface mechanically interposed between the return spring and the tappet, the contact area of the torque transfer reduction interface being configured to permit angular slip between the first and second surfaces about a rotational axis generally parallel to the pumping axis when a minimum torque is present on the return spring side of the torque transfer reduction interface rather than to transfer the minimum torque to the tappet to cause the tappet to rotate about an axis generally parallel to the pumping axis.

19. The pump of claim 18, wherein the return spring is generally tubular with a radially inner periphery defining a minimum radial dimension relative to the pumping axis and the contact area between the first and second surfaces has a maximum radial dimension relative to the pumping axis being less than the minimum radial dimension of the return spring.

20. The pump of claim 18, wherein the minimum torque is a torque at least large enough to cause angular rotation of the tappet relative to the camshaft about an axis generally perpendicular to the rotational axis of the camshaft.

21. The pump of claim 20, wherein the torque transfer reduction interface is mechanically interposed between the return spring and the tappet such that an axial compressive force biasing the tappet away from the pumping barrel and towards the camshaft along the pumping axis is operably transmitted from the return spring to the tappet through the torque transfer reduction interface.

22. The pump of claim 21, wherein at least one of the first and second surfaces is convex.

23. The pump of claim 22, wherein the convex one of the first and second surfaces is generally spherically curved.

24. The pump of claim 18, further comprising:

a spring plate axially engaged by a distal end of the return spring;

a load button providing one of the first and second surfaces of the torque transfer reduction interface, the load button being mechanically interposed between the spring plate and the tappet such that axial compressive forces of the return spring applied to the spring plate when the return spring is in a state of compression that are operably transferred to the tappet are operably transferred substantially entirely to the tappet through the load button.

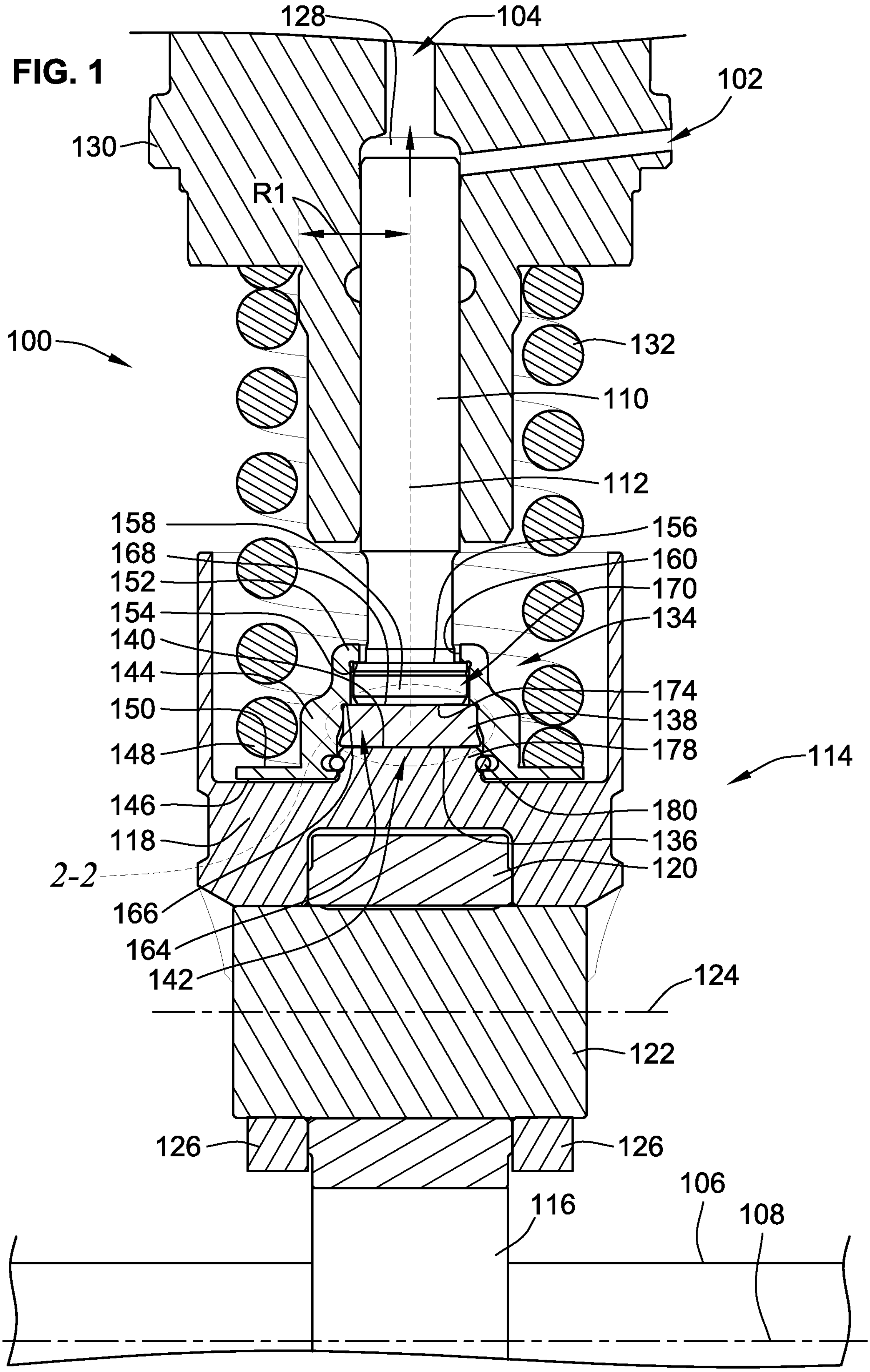
FIG. 1
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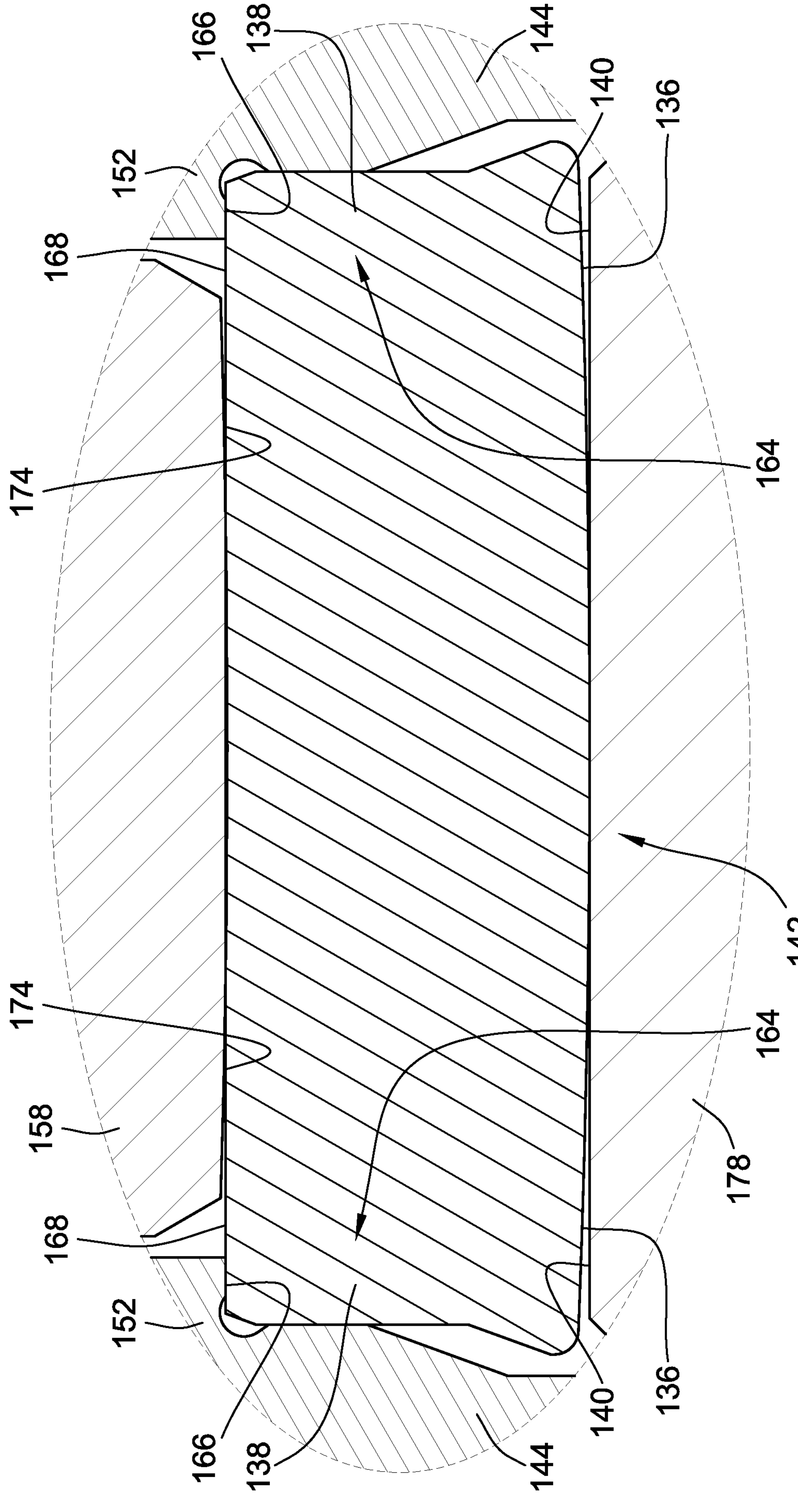

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/058464

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04B1/04 F02M59/10 F02M59/44
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 775 203 A (CUMMINS ENGINE COMPANY, INC. [US]) 7 July 1998 (1998-07-07) figure 2 column 2, line 46 - column 4, line 6 column 6, line 20 - column 8, line 6 -----	1-5,14, 18-23 6-13, 15-17,24
X A	US 4 464 099 A (LUCAS INDUSTRIES PLC [GB]) 7 August 1984 (1984-08-07) figure 1 column 1, line 50 - column 3, line 15 -----	1-5,14, 18-23 6-13, 15-17,24
A	DE 101 15 168 C1 (ORANGE GMBH [DE]) 22 August 2002 (2002-08-22) figures 2,3 paragraph [0027] - paragraph [0036] ----- -/--	1-24

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2013	23/01/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gnüchtel, Frank

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/058464

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/073078 A1 (ROBERT BOSCH GMBH [DE]) 31 March 2011 (2011-03-31) figure 2 paragraph [0022] - paragraph [0024] -----	1-24

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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