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(74) Representative: **Gregory, John David Charles**

Delphi Diesel Systems

Patent Department

Courteney Road

Gillingham

Kent ME8 0RU (GB)

(71) Applicant: **Delphi Technologies Holding S.à.r.l.**

4940 Bascharage (LU)

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(72) Inventor: **Navas Sanchez, Borja**

Chatham, Kent ME4 4DL (GB)

(54) Fuel pump

(57) A fuel pump (1) is provided for pressurising fuel in a high-pressure fuel injection system. The fuel pump (1) comprises a pump head (7), a pumping element (8), a frame (12) and a casing (3). The pump head (7) has a pumping chamber (7a) that is arranged to receive fuel to be pressurised. The pumping element (8) is arranged to reciprocate responsive to movement of a driving element (10), the pumping element (8) defining, in part, the pump-

ing chamber (7a) so that, in use, as the pumping element (8) reciprocates, a force, transferred from the driving element (10), is applied to the fuel within the pumping chamber (7a) to pressurise the fuel. The frame (12) is arranged to support the driving element (10) and the pump head (7). The casing (3) defines an internal volume (5) for containing fluid, wherein at least a part of the frame (12), at least a part of the drive element (10), and at least a part of the pumping element are received in the casing.

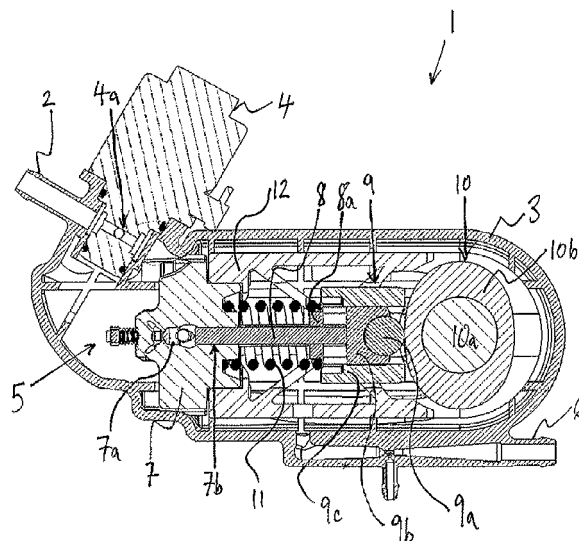


Figure 1

EP 2 557 306 A1

Description

Field of the invention

[0001] The present invention relates to the field of fuel pumps. In particular, the invention relates to a high-pressure fuel pump for supply of high-pressure fuel to a fuel injector. More specifically, but not exclusively, the present invention relates to a housing for such a pump.

Background to the invention

[0002] Fuel injection systems for modern internal combustion engines, particularly engines that utilise compression ignition, comprise a plurality of fuel injectors arranged to deliver an atomised spray of fuel to a respective combustion chamber for combustion.

[0003] In order to improve atomisation of fuel within engines utilising compression ignition it is preferable to atomise the fuel as much as possible. Greater atomisation of fuel improves the efficiency of the combustion process, which in turn improves the fuel efficiency and reduces harmful emissions such as carbon monoxide produced by the combustion process. The most common way to improve atomisation is to increase the pressure of the fuel to be injected. As such, there has been a continual desire to manufacture pumps capable of pressurising fuel to higher pressures.

[0004] Known high-pressure pumps utilise a pumping element such as a steel plunger that reciprocates inside a close-fitting guide-bore, the plunger being driven by a driveshaft. Hence, as the driveshaft rotates, its rotational force is transferred to the plunger so that the plunger reciprocates within the guide bore. Fuel enters a pumping chamber at an end of the guide bore and is then pressurised as the reciprocating plunger applies a pressurising force to the pumping chamber. The fuel is then forced through a delivery valve into a high-pressure rail ready for injection by the fuel injectors. The components of the pump are supported by the housing.

[0005] In order to increase the pressure of fuel that a high-pressure fuel pump is capable of providing, a greater energy has to be put into the system through the rotating driveshaft so that the plunger applies a greater force to the fuel. Hence, as the pressures that pumps are capable of providing has increased, so has the relative strength of the pump housing due to the increase in physical energy used within the pump.

[0006] It is common to manufacture high-pressure fuel pump housings from cast steel to provide the strength required to withstand the stresses to which high-pressure fuel pumps are subjected. As pumps capable of producing higher pressure fuel have been developed, the thickness of the steel housing has also increased to withstand the relative increases in stress.

[0007] Increasing the thickness of a cast steel pump housing results in the pump being heavier. As such, the fuel efficiency of the vehicle in which the pump is used

is reduced due to the heavier components it is having to carry. Furthermore, as the thickness of the cast steel pump housing increases, so does the overall size of the pump.

[0008] It would be desirable to provide a high pressure fuel pump that is of reduced weight and size. This is particularly of relevance to "eco-efficiency" concept vehicles, where overall weight reduction of a vehicle is a key component in improving the efficiency to thereby reduce the environmental impact of the vehicle. Furthermore, minimising the size of a pump is desirable because such a pump takes up less space within a vehicle.

[0009] Embodiments of the present invention therefore aim to at least partially mitigate one or more of the above-mentioned problems.

Summary of the invention

[0010] According to a first aspect of the present invention, there is provided a fuel pump for pressurising fuel in a high-pressure fuel injection system. The fuel pump comprises a pump head having a pumping chamber that is arranged to receive fuel to be pressurised. The fuel pump also includes a pumping element arranged to reciprocate responsive to movement of a driving element. The pumping element defines, in part, the pumping chamber so that, in use, as the pumping element reciprocates, a force, transferred from the driving element, is applied to the fuel within the pumping chamber to pressurise the fuel. The fuel pump also comprises a frame arranged to support the driving element and a casing which defines an internal volume for containing fluid. At least a part of the frame, at least a part of the drive element, and at least a part of the pumping element are received in the casing. This arrangement therefore provides a lighter, smaller pump.

[0011] The frame and the casing together provide a housing for the pump.

[0012] The frame may be arranged to hold the pump head and driving element in fixed positions relative to one another. Such an arrangement allows for correct operation of the fuel pump. In particular, a large force is transferred from the driving element to the pump head in order to pressurise fuel within the pump head to a very high pressure. The frame therefore needs to withstand such forces and keep the pump head and driving element in fixed positions relative to one another so that the pump continues to operate correctly.

[0013] The frame may be constructed from a material having higher strength than a material from which the casing is constructed. The frame is provided to support the pump head and driving element, while the casing is provided for containing fluid. Hence, only the frame has to withstand the high forces transferred from the driving element to the pump head. The casing can therefore be made from a material of lower strength than the frame because it only has to contain fluid. Alternatively, the frame and casing can be made from the same material

and the frame can be made thicker than the casing to provide the higher strength. Preferably the frame is made from aluminium because aluminium is relatively strong compared to other materials while being relatively low density compared to other materials.

[0014] The materials for the frame and casing may be selected so that they are optimised for their specific function. The material for the frame may be selected so that it is of a sufficiently high strength for supporting the forces transferred from the driving element to the pump head. The material for the casing may be selected for containing fluid.

[0015] The frame may be formed of a single piece. Forming the frame from a single piece allows for the frame to be stronger because it does not have any joins, which can lead to structural weaknesses. Furthermore, the frame may be formed of a single piece by means of an extrusion process. Such an extrusion process provides an easy means for manufacturing a frame in a single piece. Furthermore, such an extrusion process allows for additional features, such as screw holes, to be easily formed within the frame.

[0016] The casing may be formed of a plastics-based material. Such an arrangement results in a light-weight and easy to manufacture casing.

[0017] The frame may be arranged for mounting the fuel pump to an engine component. The frame supports the high-stress components of the fuel pump. It is therefore desirable to mount the fuel pump via the high-strength fuel pump frame.

[0018] The fuel pump may further comprise a mounting arrangement for connecting the frame of the fuel pump to the engine component. The mounting arrangement provides a means for providing a strong connection between the frame and the engine component.

[0019] The housing and the mounting arrangement may each comprise a complementary interference feature arranged for preventing rotation of the mounting arrangement with respect to the housing. When the fuel pump is in operation large forces are transferred between the driving arrangement and the pump head. The forces applied by these components result in the frame of the fuel pump attempting to move in response to these forces. It is therefore advantageous to include complementary interference features which will prevent rotation between the frame and the mounting arrangement, thereby helping to hold the fuel pump securely in position.

[0020] One of the complementary interference features may comprise a protrusion and the other complementary interference feature may comprise a recess. Such interlocking interference features provide a strong connection between the frame and the mounting arrangement.

[0021] The casing may comprise one or more integrated components. The one or more integrated components may include a back-leak device to aid recirculation of fluid. The one or more integrated components may include a fuel inlet to deliver fuel to the fuel pump. The one

or more integrated components may include both the back-leak device and the fuel inlet. Providing these components integrated within the housing provides a smaller and easier to manufacture fuel pump.

[0022] The driving element may be formed from a plurality of parts including a shaft portion and a cam portion. Such an arrangement is advantageous when using a frame formed of a single piece. The cam portion may be constructed from a higher strength material than the shaft portion. This is because the cam portion bears the majority of the load which is transferred to the pump head for pressurising the fuel. Such an arrangement provides a cheaper to manufacture driving element because only the expensive strong material is utilised for the part requiring a strong material.

[0023] The pump head may be received within the casing. Including the pump head within the casing improves cooling of the pump head.

[0024] Embodiments of the invention provide a high pressure fuel pump which is of lighter weight than currently known pumps. A high strength frame is provided to bear the pumping loads by supporting the high stress portions of the pump, such as the cam arrangement and the pump head, and a lightweight casing is then provided to seal the pump to prevent leakage of fuel from the pump.

[0025] Embodiments of the invention provide a high pressure fuel pump that is smaller than known fuel pumps. Such embodiments utilise a support frame and lightweight casing. The casing can be relatively thin, and as such, the overall thickness of the housing is reduced because only a strong frame support is provided, rather than a strong housing that encases the whole pump.

[0026] Embodiments of the invention reduce the cost and time for prototyping new pumps. In particular, the frame can be extruded from metal and a plastic moulded shell can be utilised to construct the casing. Such techniques do not require the slow and expensive provisions required to construct a cast steel housing.

Brief description of the drawings

[0027] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which like reference numerals are used for like parts, and in which:

Figure 1 illustrates a cross-sectional view of a pump according to a first embodiment of the present invention;

Figure 2 provides an exploded view of the pump of Figure 1;

Figure 3 illustrates a frame of a pump housing of the pump of Figure 1;

Figure 4 illustrates a casing of the pump of Figure 1;

Figure 5 provides an exploded view of a fixing arrangement of the pump in Figure 1;

Figure 6 provides an exploded view of the fixing arrangement of Figure 5 from an alternative angle;

Figure 7 provides an exploded view of the cam arrangement illustrated in Figures 1 and 2; and

Figure 8 provides an exploded view of an alternative cam arrangement.

Detailed description of embodiments of the invention

[0028] Reference shall firstly be made to Figures 1 and 2, which provide two alternative views of a pump 1 provided in accordance with a first embodiment of the present invention. The pump 1 shall initially be described primarily in respect of its operation.

[0029] Low-pressure fuel enters the pump 1 through a fuel inlet 2, which is integrated into a casing 3 of the pump 1. The fuel then passes through an inlet metering valve (IMV) 4a of an IMV arrangement 4 mounted on the casing 3, which controls the rate of flow of fuel into the pump 1. The casing 3 forms part of a pump housing and defines an internal cavity 5 in which pumping and driving components of the pump 1 are arranged, the internal cavity 5 being filled with fuel. The IMV arrangement 4 is partially arranged between the fuel inlet 2 and the internal cavity 5; fuel therefore passes from the fuel inlet 2 through the IMV 4a and into the internal cavity 5.

[0030] The fuel within the internal cavity 5 acts as a lubricant to the moving parts of the fuel pump 1, and it also acts to cool components of the pump 1 by absorbing heat generated in the pumping process so that the heat is transferred away from the pumping components of the pump 1. In order to aid the cooling process a back-leak device 6 such as a venturi device is provided to allow fuel to be drawn from internal cavity 5 and returned to a low pressure drain or engine cam box, so that the fuel is recirculated. The back-leak device 6 therefore aids the recirculation of fuel so that the heat generated by the pumping components is transferred away from the fuel pump 1.

[0031] The pumping components include a pump head 7, a pumping element in the form of a plunger 8 and a drive arrangement comprising a follower arrangement 9 and a driveshaft or cam arrangement 10. The pumping process takes place within the pump head 7. The pump head is therefore made of a strong material, such as hardened steel, in order to withstand the high-pressure fuel which is pressurised within a pumping chamber 7a of the pump head 7, in addition to the large forces applied to the pump head 7 by the pumping element 8 in order to pressurise the fuel.

[0032] The pumping chamber 7a of the pump head 7 is arranged at one end of a plunger bore 7b provided in

the pump head 7 and is a cavity comprising a low-pressure fuel inlet (not shown) for receiving fuel from the internal cavity 5 defined by the casing 3, and a high-pressure fuel outlet (not shown) in the form of an outlet valve.

5 The pumping chamber 7a is defined in part by a pumping head at a first end of the plunger 8. The plunger 8 is arranged to reciprocate so that a pumping head of the plunger increases and decreases the volume of the pumping chamber 7a. As the volume of the pumping chamber decreases, the pressure of fuel within the pumping chamber 7a increases. When the fuel within the pumping chamber 7a reaches a predetermined pressure, the outlet valve opens allowing the high-pressure fuel to pass through into a high-pressure rail (not shown) where the fuel is stored ready for injection by one or more fuel injectors (not shown).

10 **[0033]** At a second end of the plunger 8, remote from the pumping chamber 7a, the follower arrangement 9 is arranged to cooperate with the cam arrangement 10 to transform a rotational movement of the cam arrangement 10 into the reciprocal movement of the plunger 8 within the plunger bore 7b.

15 **[0034]** The cam arrangement 10 is provided with a shaft portion 10a located at least partially outside the casing 3 of the pump 1 to engage with a drive source (not shown), such as a drive gear. The cam arrangement 10 rotates responsive to the input force provided by the drive gear. The shaft portion 10a of the cam arrangement 10 is also located in part within the internal cavity 5 of the casing 3, and has a cam portion 10b connected on the shaft 10a at a portion within the internal cavity 5.

20 **[0035]** The follower arrangement 9 comprises a roller 9a which abuts the cam 10b so that the roller 9a and cam 10b are communicatively coupled. The roller 9a is held within a roller shoe 9b connected to the second end of the plunger 8. As the cam 10b rotates, the roller 9a rotates within the roller shoe 9b. The arrangement of the roller 9a and roller shoe 9b limits the transfer of lateral movement from the cam 10b to the plunger 8, while transferring reciprocal movement of the cam 10b to the plunger 8. A spring 11 is maintained in position between the pump head 7 and a spring seat 8a mounted on the plunger 8, in order to urge the plunger 8, and the roller shoe 9b connected thereto, into contact with the cam 10b. Due to the spring 11, the follower arrangement 9 continually follows the reciprocating movement of the cam 10b.

25 **[0036]** The follower arrangement 9 also includes a shoe guide 9c, which is provided around the peripheral surface of the roller shoe 9b in order to guide the movement of the roller shoe 9b. The guide 9c therefore allows the roller shoe 9b to move along the axis of the plunger 8, allowing reciprocating movement, but restricting lateral movement, of the guide shoe 9c. The rotation of the cam arrangement 10 exerts a lateral force on the follower arrangement 9 and as such the shoe guide 9c is constructed of a strong material in order to resist such lateral movement and to withstand the stress associated with such resistance.

[0037] While the above-mentioned follower arrangement 9 has been described as a roller-based arrangement it will be appreciated that any suitable following arrangement could be used (e.g. a tappet or other intermediate drive component).

[0038] The pump housing includes a frame 12 in addition to the casing 3. The frame 12 is provided to support various pumping and driving components, in particular, the pumping components 7, 9, 10 that are subjected to high levels of stress due to the pumping process. Hence, the frame 12 is arranged to support the pump head 7, the roller shoe 9, and the shaft 10a of the cam arrangement 10. The frame 12 is therefore made of a relatively strong material, such as aluminium, in order to withstand the high levels of stress within the pump 1, particularly due to the forces being transferred from the cam arrangement 10 to the plunger 8 and then into the fuel within the pump head 7.

[0039] In order to aid rotation of the cam arrangement 10, and prevent excessive load and wear to the frame 12, bushes 13a, 13b are provided at the portions of the frame 12 that support the cam arrangement 10.

[0040] As can be seen in Figure 2, a mounting arrangement 14 is provided with a mounting plate 14a external to the casing 3 which connect the pump 1 to the engine. The mounting arrangement 14 connects to the frame 12 through the casing 3 in order to provide a solid support for the frame 12 and therefore the pump 1. Since the frame 12 and mounting arrangement 14 are connected through the casing 3, the mounting arrangement 14 includes a plurality of seals 14b, 14c in order to prevent leakage of fuel through the casing 3.

[0041] Each of the components of the pump 1 shall now be discussed in more detail with reference to various figures.

[0042] The construction of the frame 12 shall be discussed with further reference to Figure 3, which shows the frame 12 of the pump of the first embodiment of the present invention.

[0043] The frame 12 is provided with two cam support sections 12a, 12b, which each define a hole 12c, 12d through which the cam arrangement 10 (shown in Figures 1 and 2) can be supported, wherein the cam 10b is located between the two cam support sections 12a, 12b. The holes 12c, 12d defined by the cam support sections 12a, 12b respectively are shaped so as to complement the external surface of the shaft 10a of the cam arrangement 10. Hence, in this case the holes 12c, 12d are circular to complement the cylindrical shape of the shaft 10a of the cam arrangement 10. As such, smooth rotation of the cam arrangement 10 is possible. The dimensions of the frame 12 are arranged so that within the holes 12c, 12d defined by each cam support section 12a, 12b one of the bushes 13a, 13b can be placed in order to aid rotation of the shaft 10a of the cam arrangement 10. The fuel in the internal cavity 5 defined by the internal walls of the casing 3 helps to lubricate the frame 12 and bushes 13a, 13b in order to aid smooth rotation of the shaft 10a

of the cam arrangement 10 and minimise wear. The cam support sections 12a, 12b bear the majority of the weight and stress of the cam arrangement 10. However, the mounting arrangement 14 bears a portion of the load applied to the cam support section 12a which is adjacent to the mounting arrangement 14.

[0044] The frame 12 is also provided with a pump head support section 12e. This section 12e has a hole 12f for receiving the pump head 7. In particular, a front face of the pump head 7 protrudes, at least partially, through this hole 12f. The front face of the pump head 7 includes a recess defining, in part, the pumping chamber 7a into which the pumping head of the plunger 8 is inserted to thereby define the pumping chamber 7a.

[0045] A plurality of screw holes 12g (only one shown in Figure 3) are provided in the pump head support section 12e of the frame 12 through which screws (not shown) can connect the pump head 7 to the frame 12. A strong clamping of the pump head 7 to the frame 12 is required in order to prevent the pump head 7 from being separated from the frame 12 when the plunger 8 drives into the pump head 7, in such a way that a force is provided that urges the pump head 7 away from the frame 12. Alternatively, the frame 12 could be arranged to provide at least one support member (not shown) that abuts a rear face of the pump head so that connection screws are not relied upon for holding the pump head 7 onto the frame 12.

[0046] The frame 12 is also provided with shoe-guide support sections 12h (only one shown), which includes a plurality of struts (not shown) that support the shoe-guide 9c.

[0047] The cam support sections 12a, 12b, pump head support section 12e and the shoe-guide support sections 12h are joined together by the main structure of the frame 12. Structural rigidity is required between these sections 12a, 12b, 12e, 12h, and in particular the cam support sections 12a, 12b and the pump head support section 12e because the pressurisation of the fuel is achieved by the relative movement of the plunger 8, driven by the cam arrangement 10, into the pump head 7. Hence, the position of the pump head 7 with respect to the cam arrangement 10 needs to remain constant in order to allow for correct operation of the pump 1.

[0048] Holes or cut-outs 12i are provided within the main body of the frame 12 in order to reduce the weight of the frame 12 without reducing the relative strength of the frame 12 so that the frame 12 is able to provide strong support to the components of the pump subjected to high levels of stress.

[0049] It will be appreciated that while the cam support sections 12a, 12b, pump head support section 12e and the shoe-guide support sections 12h are supported by the main body of the frame 12 in this embodiment of the invention, alternatively, strut supports could be provided between each of the sections of the frame 12 in order to link the sections together. Use of strut supports between the sections of the frame 12 could help to further reduce

the weight of the frame 12, and in certain arrangements allow for a reduction in the size of the frame 12.

[0050] In this example, the frame 12 is also provided with attachment holes 12j, 12k, 12l, 12m for connecting the pump 1, via the frame 12, to the mounting arrangement 14. The holes 12j, 12k, 12l, 12m and their relationship to the mounting arrangement 14 shall be discussed when the mounting arrangement 14 is described in detail with respect to Figures 5 and 6.

[0051] The frame 12 is made by extruding an aluminium bar. The extrusion process is fast and cheap to perform. By forming the frame 12 by an extrusion process the frame 12 can be formed of one part. That is, it is extruded from a single bar of metal and as such no parts have to be joined. In contrast, casting processes require two or more parts to be cast, which are then joined together. There is a risk of structural weaknesses forming at the joins between these parts. Hence, the extrusion process overcomes these problems.

[0052] Furthermore, since the frame 12 is extruded, the amount of cutting and drilling of the frame is minimised. In particular, the extrusion process allows for certain characteristics of the frame 12, such as holes, to be formed in the frame 12 during the extrusion process. In contrast, casting techniques require all characteristics to be added after the casting, therefore leading to further structural weaknesses.

[0053] It will be appreciated that while the frame 12 is described as being made of aluminium, any suitably strong material could be utilised. In particular, any suitable metal could be used or other materials like a composite plastic or composite plastic encapsulated in sintered metal. It is noted that while an extrusion process is preferable for constructing the frame 12, other construction processes such as casting could be utilised.

[0054] The casing 3, which defines the internal cavity 5, is arranged to enclose the frame 12 and the pumping and driving components that the frame 12 supports. In other words, the pumping and driving components are at least partially arranged within the internal cavity defined by the frame 12. The casing 3 therefore provides a fluid tight shell around the pumping components so that fuel does not leak from the internal cavity.

[0055] While in Figure 1 the casing 3 is shown to enclose all pumping and driving components of the pump 1 it will be appreciated that the casing 3 is arranged to define an internal cavity containing fuel for cooling and lubrication purposes. The moving driving and pumping parts of the pump 1, such as the plunger 8, follower arrangement 9, and cam arrangement 10 therefore require such lubrication and cooling. As such, it will be appreciated that it is not necessary for the whole of the pump head 7 to be enclosed within the casing 3. The casing could be provided so that it joins a peripheral surface of the pump head 7 or the front face of the pump head 7. In such circumstances the front face of the pump head 7 would be in fluid communication with the fuel within the internal cavity 5, and at least part of the side portion and

the whole of the rear portion of the pump head 7 would be external to the casing 3. It is noted that due to the constant flow of fuel through the pump head, the heat created within the pump is, at least in part, transferred away by the pressurised fuel, and therefore cooling of the pump head is not as important as cooling of the moving components of pumping process.

[0056] The casing 3 is formed of two parts 3a, 3b, as shown in Figure 2. The parts 3a, 3b are arranged to fit around the components attached to and within the frame 12. The two parts 3a, 3b of the plastic casing can then be joined together so that the two-part casing 3 seals fluid within. The two parts can be joined by any method capable of providing a fluid tight bond.

[0057] Figure 4 shows one half 3a of the casing 3. In Figure 4, it can be seen that the casing 3 has a plurality of internal supporting struts 3s. The supporting struts 3s stiffen the casing 3 to improve the strength of the casing 3. As such it is possible to have a thinner casing 3, while still providing sufficient strength. The struts 3s could also be provided to abut the outer surface of the frame 12 so that the casing 3 is tightly formed around the frame 12.

[0058] In this embodiment of the invention the frame 12 is only joined to the casing 3 via the mounting arrangement 14. However, it will be appreciated that the casing 3 could be connected to the frame 12 in various ways, such as by utilisation of one or more connection screws having suitable sealing to prevent leakage from the casing 3.

[0059] The two casing parts 3a, 3b are formed from plastic using an injection moulding technique. As such, high-frequency welding would provide a suitable bond between the two parts 3a, 3b. However, other materials such as a metal could be used for the casing 3. For example, an aluminium frame 12 and casing 3 could be provided. Since the casing 3 only needs to provide fluid tightness it could be made much thinner than the frame 12. Furthermore, due to the relative strength of metal compared to plastic, a metal casing 3 could be made much thinner than a plastic casing 3. Due to its conductive properties, a metal casing 3 would also assist in transferring heat away from the fuel within the internal cavity.

[0060] While in the embodiment of the invention discussed in respect of Figures 1 and 2 the internal cavity 5 defined by the casing 3 is filled with fuel, it will be appreciated that other fluid could be provided within the internal cavity 5. For example, specific cooling/lubrication fluid could be contained in the internal cavity. In such circumstances, the IMV arrangement 4 would connect directly, or via a contained channel, from the fuel inlet 2 to the pump head 7. In such an arrangement a cooling fluid inlet (not shown) could be provided, and the back-leak device 6 would help to recirculate the cooling fluid.

[0061] As well as defining the internal cavity 5, the casing 3 also defines various features of the fuel pump 1, as discussed below.

[0062] The casing 3 includes an IMV connection portion 3b, which is arranged to enable the shell of the IMV

arrangement 4 to be connected to the pump 1. The IMV connection portion 3b defines a hole 3c in which a portion of the IMV arrangement 4 can be positioned, so that the IMV 4a can connect to the fuel inlet 2. One or more connection holes 3d can be provided within the casing 3 to enable the IMV arrangement 4 to be attached to the casing so that the IMV arrangement 4 is held in place on the pump 1.

[0063] The casing 3 also provides an integrated back-leak device 6, and an integrated fuel inlet 2. Integrating these components into the casing 3 is advantageous when the casing 3 is constructed from plastic using an injection moulding method because the components are formed as part of the casing 3 in the moulding process. Furthermore, integrating these components within the casing 3 simplifies the overall manufacturing process of the fuel pump 1 and reduces the size of the fuel pump 1.

[0064] The housing, which includes the frame 12 and the casing 3, is much smaller than known housings. This is because the minimum structural support required can be provided by the frame 12, and then a comparatively thin and light casing 3 can be provided to provide a fluid-tight seal for the pump 1. Overall, this allows for the overall size of the housing and therefore the pump 1 to be reduced. In addition, the materials used for the frame 12 and casing 3 can be selected so as to best suit their respective functions, which allows for the weight of the housing and the therefore pump 1 to be reduced.

[0065] A further advantage of such a housing construction is that it is possible to place the IMV arrangement 4 much closer to the pump head 7 than is possible in a fuel pump that utilises a cast steel housing. This is because the frame 12 can be provided only in those portions that require support, and the casing 3 can be arranged to closely surround this frame 12, enabling the IMV arrangement 4 to be positioned close to the pump head 7. As such, the overall pump head 7 can be reduced further.

[0066] While the frame 12 has been described as being arranged within the casing 3 above, it will be appreciated that the frame 12 could be provided so that it is only partially within the casing 3. For example, the main structure of the frame 12 could be provided outside the casing 3 with support arms extending through the casing 3 to support the high stress components of the pump 1. In such a case, the mounting arrangement 14 can be easily connected to the frame 12, or even be formed integrally with the frame 12.

[0067] The mounting arrangement 14 shown in Figure 2 shall now be described in further detail with reference to Figures 5 and 6.

[0068] The mounting arrangement 14 comprises a mounting plate 14a, which is arranged to connect to a component of the engine to secure and stabilise the pump 1. The mounting plate 14 is a substantially planar structure with a plurality of holes or cutaways to reduce the weight of the plate 14a. The mounting plate 14a is provided with a plurality of screw holes 14d, 14e, 14f for screws (not shown) to connect the mounting plate to the

engine. Further screw holes 14g, 14h, 14i, 14j are provided to allow the mounting plate 14 to be connected by screws through holes in the casing 3 and connect to the frame 12. As such, one face of the mounting plate 14a is arranged to sit flush against the casing 3, connected through the casing 3 to the frame 12, so that the casing 3 is held between the mounting plate 14a and the frame 12.

[0069] Since the screws for connecting the mounting plate 14a to the frame 12 pass through the casing 3 it is necessary to provide a mounting arrangement sealing means. This is achieved by providing first and second seals 14b, 14c, which seal the gap between the mounting plate 14a and the casing 3, and the gap on the outer surface of the mounting plate 14a, respectively.

[0070] The first seal 14b takes the form of a gasket positioned between the mounting plate 14a and the casing 3. The gasket 14b is arranged so that it surrounds all of the screw holes in the casing 3 and those 14g, 14h, 14i, 14j in the mounting plate 14 thereby creating an internal cavity between the mounting plate 14a and the casing 3 for fluid. The gasket 14b is clamped between the mounting plate 14a and casing 3 due to the screws clamping the frame 12 and the mounting plate 14a together. The gasket 14b therefore provides a fluid-tight seal between the casing 3 and the mounting plate 14a. Alternatively, the first seal could be provided by a plurality of gaskets, each provided around an individual screw hole.

[0071] The second seal 14c takes the form of a rubber O-gasket and is arranged on an outer surface of the mounting plate 14a. The O-gasket 14c prevents fuel leaking from around the heads of the screws that pass through the mounting plate 14a.

[0072] To prevent rotation of the housing with respect to the mounting plate 14a, the casing 3 is provided with a plurality of protrusions 3m, which are arranged to engage with a plurality of complementary recesses 14k within the mounting plate 14a. In use, this engagement of the casing 3 and mounting plate 14a helps to prevent rotation of the mounting plate 14a with respect to the casing 3. Hence, this feature of the mounting arrangement 14 provides an interference which is radial with respect to the shaft 10a of the cam arrangement 10, in order to help prevent rotation of the mounting arrangement 14.

[0073] It will be appreciated that the radial interference features provided between the casing 3 and the mounting plate 14a could include further protrusions in the frame 12 which protrude into the rear of the protrusions 3m in the casing 3. As such, the frame 12 would support the protrusions 3m and thereby provide additional resistance to the relative rotation of the housing and mounting plate 14.

[0074] The mounting plate 14a can be extruded from an aluminium bar. Such a manufacturing process is cheap and quick. However, any suitable material or manufacturing process could be used.

[0075] The construction of the cam arrangement 10 shown in Figures 1 and 2 shall now be considered in detail with reference to Figure 7.

[0076] In general, known driveshafts are constructed from a single piece of metal and supported by a two-part cast steel housing, which is constructed around the drive-shaft. However, when utilised with an extruded aluminium frame or any fixed frame structure it is not possible to utilise a standard driveshaft.

[0077] In the embodiment of the invention shown in Figures 1 and 2 a multiple part cam arrangement 10 is provided. The cam arrangement 10 includes three portions: the shaft 10a, the cam 10b and a rear bearing journal 10c. The shaft 10a runs along the length of the cam arrangement 10 and the cam 10b and rear bearing journal 10c are mounted thereon so that the cam arrangement 10 can be constructed within the fixed frame 12.

[0078] The shaft 10a is an elongate structure with a stepped cylindrical form, having a plurality of cylindrical parts, which reduce in diameter towards one end of the shaft 10. The shaft has a first reduced diameter portion 10aa onto which the cam 10b is press-fitted, and a neighbouring second reduced diameter section 10ab at an end of the shaft 10a onto which the rear bearing journal 10c is press-fitted. The second reduced diameter section 10ab has a smaller diameter than the first reduced diameter section 10aa.

[0079] In order to assemble the cam arrangement 10 within the frame 12 it is firstly necessary to insert the cam 10b through the gap between the two cam support sections 12a, 12b in Figure 3. Then, the shaft 10a is inserted through the first cam support section 12a of the frame 12 and through the cam 10b and into the rear bearing journal 10c which is arranged to support the shaft 10a within the second cam support section 12b of the frame 12.

[0080] Figure 8 shows an alternative cam arrangement 100, which utilises a key interference join. In this embodiment of the invention the cam arrangement 100 includes a shaft 100a, a cam 100b, a rear bearing journal and two engagement elements (or keys) 100d, 100e. The shaft 100a and the cam 100b are provided with recessed portions 100aa, 100ba, 100bb (or keyways) with which the engagement elements 100d, 100e engage. The engagement elements 100d, 100e therefore act as intermediate connecting parts which provide a join or bridge between the shaft 100a and the cam 100b in order to help prevent the parts of the cam arrangement 100 moving out of position with respect to one another. The arrangement 100 of Figure 8 therefore provides a driveshaft arrangement 100 which is stronger than the above-mentioned arrangement 10 that relies upon press-fitting of parts.

[0081] It will be appreciated that while press-fit and key-interference fit arrangements have been described, the parts of the cam arrangement could be connected by any suitable means such as a serial interference, a thermal expansion interference, a spline interference, or by hyrdo-forming.

[0082] Constructing the cam arrangement 10, 100

from multiple parts allows for a cheaper cam arrangement to be constructed compared to a driveshaft made from a single piece. In particular, the cam 10b, 100b can be made from high-tensile steel because it takes the majority of the stress and then the shaft and rear bearing journal can be made of cheaper grade steel.

[0083] The cam arrangement 10 of the illustrated embodiment serves as a drive element of the pump for transferring a driving force to the pumping element for pressurising fuel within the pump head. It will be appreciated that other drive elements could be contemplated.

[0084] For example, even though use of a fixed frame 12 with a cam arrangement 10 made of multiple parts has been described herein it will be appreciated that in certain circumstances it may be preferable to utilise a drive element comprising a single-part driveshaft and a frame made of multiple parts.

[0085] The invention has been described with use of a linear pumping arrangement, wherein a cam 10b, 100b drives an elongate plunger 8 to drive into a pumping chamber 7a. However, it will be appreciated that alternative pumping arrangements could be used. For example, a drive element comprising a rocker-arm type pumping arm can be utilised. In such a case, drive members of the rocker arrangement could be supported by the frame in a similar way to the cam arrangement illustrated in Figure 1.

[0086] The above-mentioned embodiments of the present invention have been described with reference to a single pump 1 having a single pump head 7 and single cam arrangement 10. However, it will be appreciated that the principles of the present invention apply equally to pumping systems including multiple pumping heads, with one or more driveshafts.

[0087] Further variations and modifications will be apparent to a person skilled in the art without departing from the scope of the invention as defined in the appended claims.

Claims

1. A fuel pump (1) for pressurising fuel in a high-pressure fuel injection system, the fuel pump (1) comprising:

a pump head (7) having a pumping chamber (7a) that is arranged to receive fuel to be pressurised; a pumping element (8) arranged to reciprocate responsive to movement of a driving element (10), the pumping element (8) defining, in part, the pumping chamber (7a) so that, in use, as the pumping element (8) reciprocates, a force, transferred from the driving element (10), is applied to the fuel within the pumping chamber (7a) to pressurise the fuel; a frame (12) arranged to support the driving element (10) and the pump head (7); and

- a casing (3) defining an internal volume (5) for containing fluid;
wherein at least a part of the frame (12), at least a part of the drive element (10), and at least a part of the pumping element (8) are received in the casing (3).
2. The fuel pump (1) according to claim 1, wherein the frame (12) is arranged to hold the pump head (7) and driving element (10) in fixed positions relative to one another to support the transfer of force from the driving element (10) to the pump head (7).
 3. The fuel pump (1) according to claim 1 or claim 2, wherein the frame (12) is constructed from a material having higher strength than a material from which the casing (3) is constructed.
 4. The fuel pump (1) according to any preceding claim, wherein the frame (12) is formed of a single piece.
 5. The fuel pump (1) according to claim 4, wherein the frame (12) is formed of a single piece by means of an extrusion process.
 6. The fuel pump (1) according to any preceding claim, wherein the casing (3) is formed of a plastics-based material.
 7. The fuel pump (1) according to any preceding claim, wherein the frame (12) is arranged for mounting the fuel pump (1) to an engine component.
 8. The fuel pump (1) according to claim 7, further comprising:

a mounting arrangement (14) for connecting the frame (12) of the fuel pump (1) to the engine component.
 9. The fuel pump (1) according to claim 8, wherein the housing (3, 12) and the mounting arrangement (14) each comprise a complementary interference feature (3m, 14k) arranged for preventing rotation of the mounting arrangement (14) with respect to the housing (3, 12).
 10. The fuel pump (1) according to claim 9, wherein one of the complementary interference features comprises a protrusion (3m) and the other complementary interference feature comprises a recess (14k).
 11. The fuel pump (1) according to any preceding claim, wherein the casing (3) comprises one or more integrated components (2, 6) including one or more of a back-leak device (6) to aid recirculation of fluid, and a fuel inlet (2) to deliver fuel to the fuel pump (1).

12. The fuel pump (1) according to any preceding claim, wherein the driving element (10) is formed from a plurality of parts including a shaft portion (10a) and a cam portion (10b).
13. The fuel pump (1) according to claim 12, wherein the cam portion (10b) is constructed from a higher strength material than the shaft portion (10a).
14. The fuel pump (1) according to any preceding claim, wherein the pump head (7) is received within the casing (3).
15. The fuel pump (1) according to any preceding claim, wherein the frame comprises at least one bearing (12c, 12d, 13a, 13b) arranged to support the drive element (10) for rotational movement with respect to the bearing (12c, 12d, 13a, 13b).

Amended claims in accordance with Rule 137(2) EPC.

1. A fuel pump (1) for pressurising fuel in a high-pressure fuel injection system, the fuel pump (1) comprising:

a pump head (7) having a pumping chamber (7a) that is arranged to receive fuel to be pressurised;
a pumping element (8) arranged to reciprocate responsive to movement of a driving element (10), the pumping element (8) defining, in part, the pumping chamber (7a) so that, in use, as the pumping element (8) reciprocates, a force, transferred from the driving element (10), is applied to the fuel within the pumping chamber (7a) to pressurise the fuel;
a frame (12) arranged to support the driving element (10) and the pump head (7);
and
a casing (3) defining an internal volume (5) for containing fluid;
wherein at least a part of the frame (12), at least a part of the driving element (10), and at least a part of the pumping element (8) are received in the casing (3).

2. The fuel pump (1) according to claim 1, wherein the frame (12) is arranged to hold the pump head (7) and driving element (10) in fixed positions relative to one another to support the transfer of force from the driving element (10) to the pump head (7).
3. The fuel pump (1) according to claim 1 or claim 2, wherein the frame (12) is constructed from a material having higher strength than a material from which the casing (3) is constructed.

4. The fuel pump (1) according to any preceding claim, wherein the frame (12) is formed of a single piece.

drive element (10) for rotational movement with respect to the bearing (12c, 12d, 13a, 13b).

5. The fuel pump (1) according to claim 4, wherein the frame (12) is formed of a single piece by means of an extrusion process. 5

6. The fuel pump (1) according to any preceding claim, wherein the casing (3) is formed of a plastics-based material. 10

7. The fuel pump (1) according to any preceding claim, wherein the frame (12) is arranged for mounting the fuel pump (1) to an engine component. 15

8. The fuel pump (1) according to claim 7, further comprising:

a mounting arrangement (14) for connecting the frame (12) of the fuel pump (1) to the engine component. 20

9. The fuel pump (1) according to claim 8, wherein the casing (3) and the mounting arrangement (14) each comprise a complementary interference feature (3m, 14k) arranged for preventing rotation of the mounting arrangement (14) with respect to the casing (3). 25

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10. The fuel pump (1) according to claim 9, wherein one of the complementary interference features comprises a protrusion (3m) and the other complementary interference feature comprises a recess (14k). 35

11. The fuel pump (1) according to any preceding claim, wherein the casing (3) comprises one or more integrated components (2, 6) including one or more of a back-leak device (6) to aid recirculation of fluid, and a fuel inlet (2) to deliver fuel to the fuel pump (1). 40

12. The fuel pump (1) according to any preceding claim, wherein the driving element (10) is formed from a plurality of parts including a shaft portion (10a) and a cam portion (10b). 45

13. The fuel pump (1) according to claim 12, wherein the cam portion (10b) is constructed from a higher strength material than the shaft portion (10a). 50

14. The fuel pump (1) according to any preceding claim, wherein the pump head (7) is received within the casing (3). 55

15. The fuel pump (1) according to any preceding claim, wherein the frame comprises at least one bearing (12c, 12d, 13a, 13b) arranged to support the

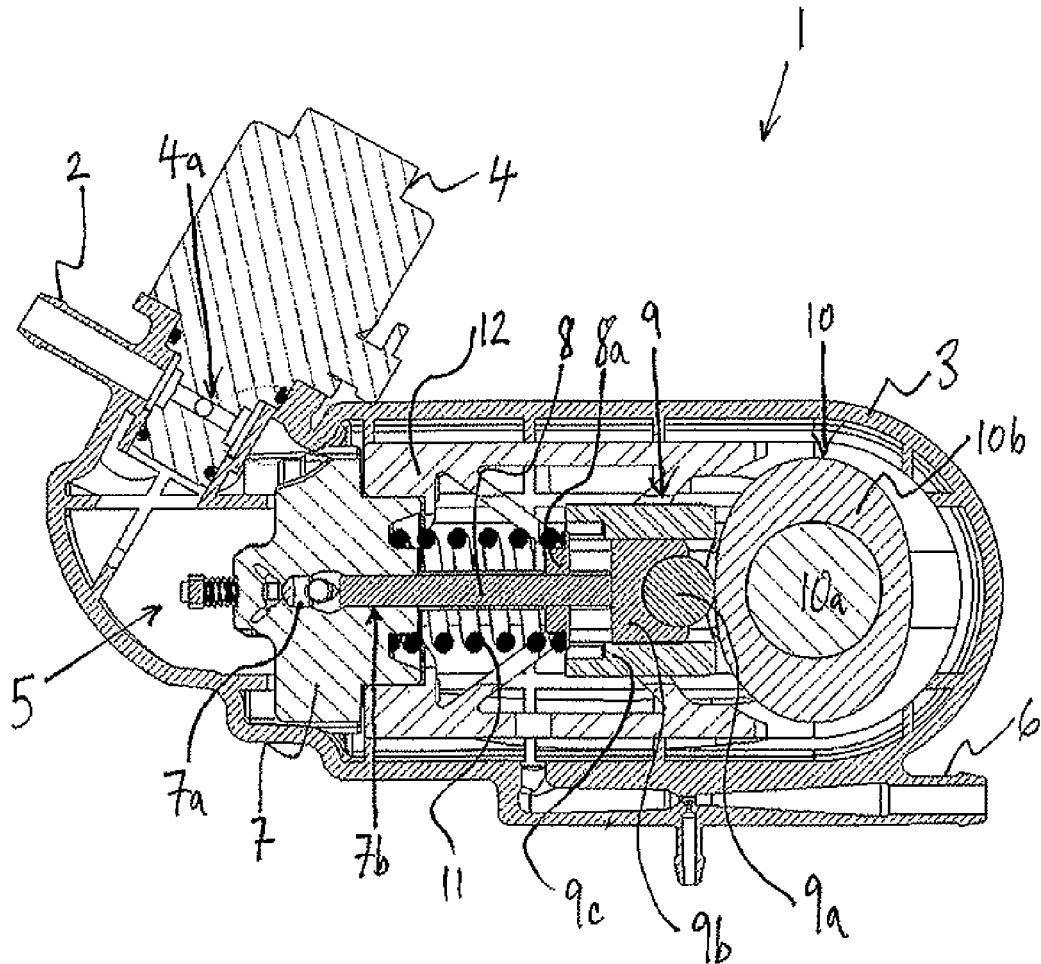


Figure 1

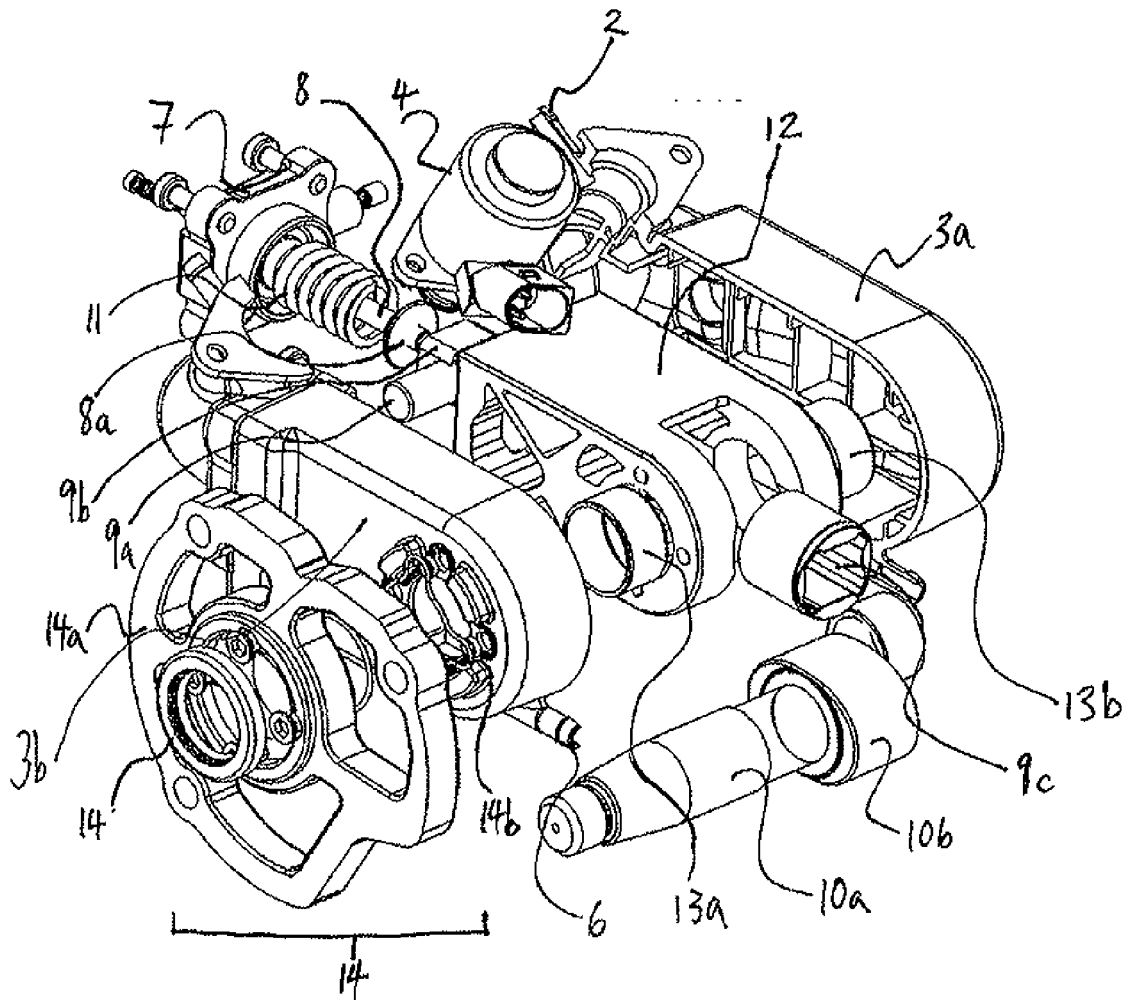


Figure 2

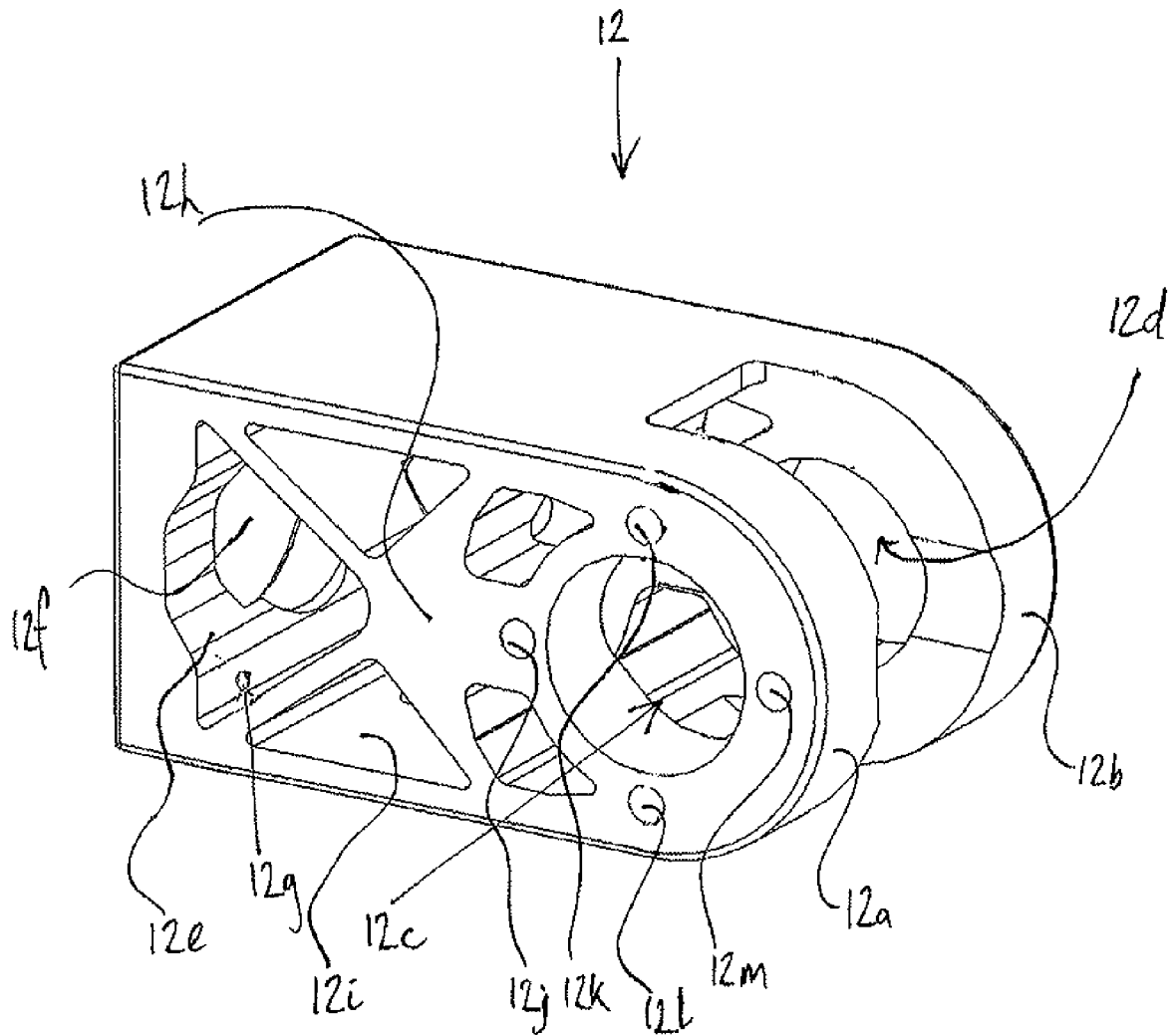


Figure 3

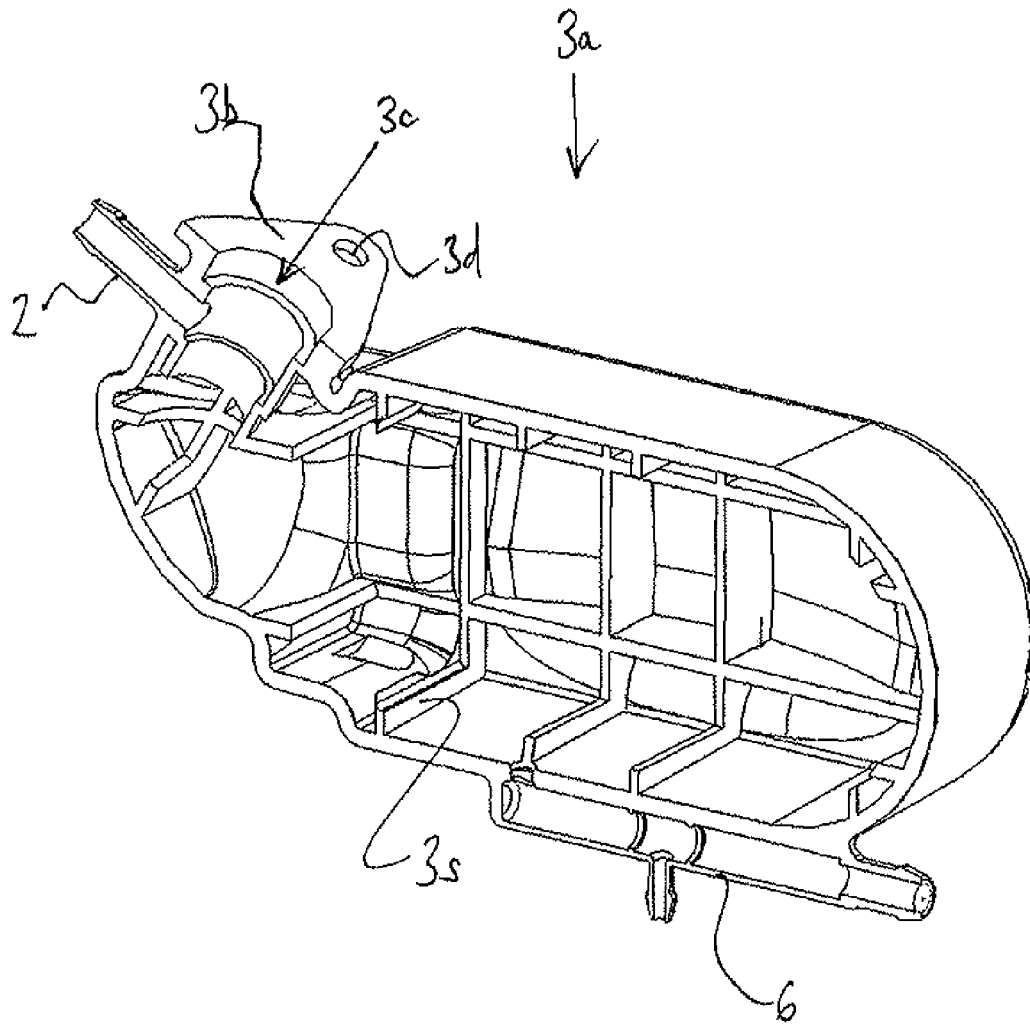
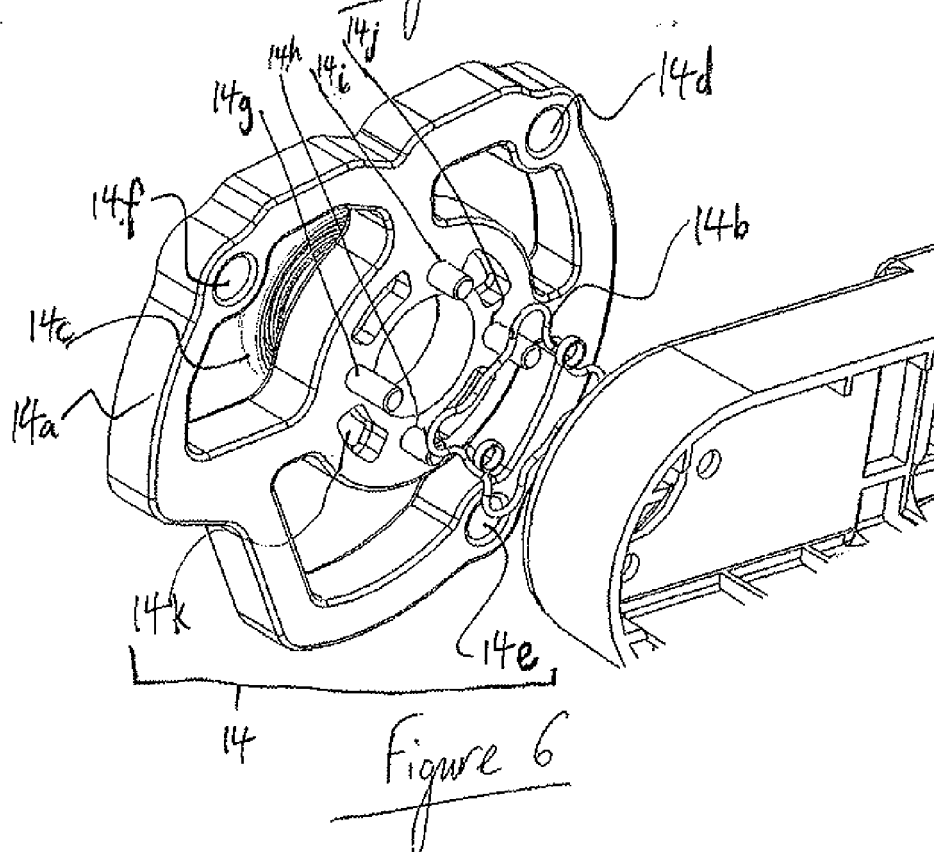
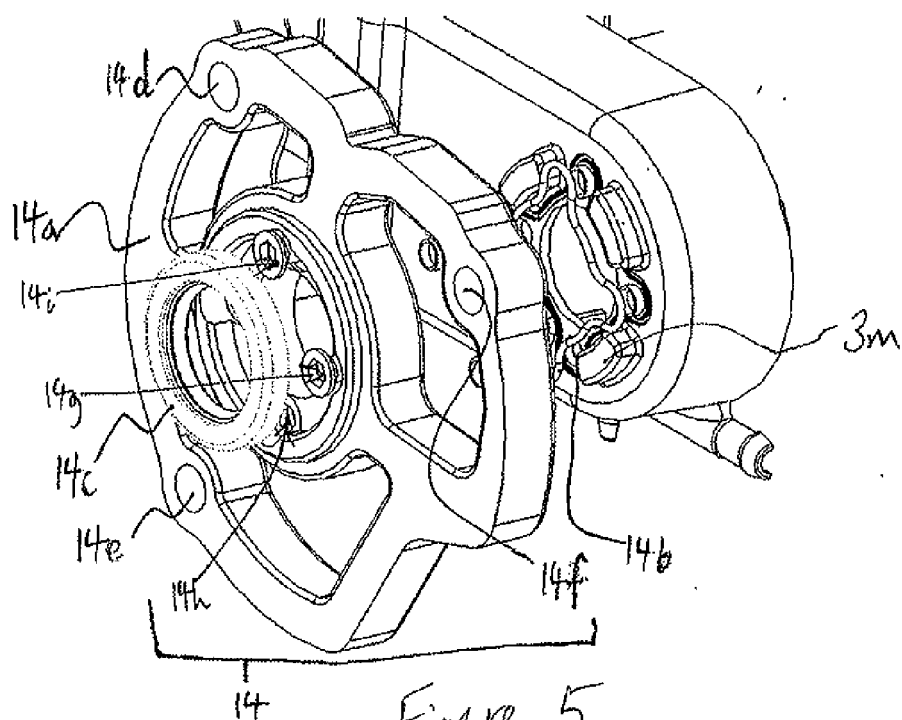


Figure 4



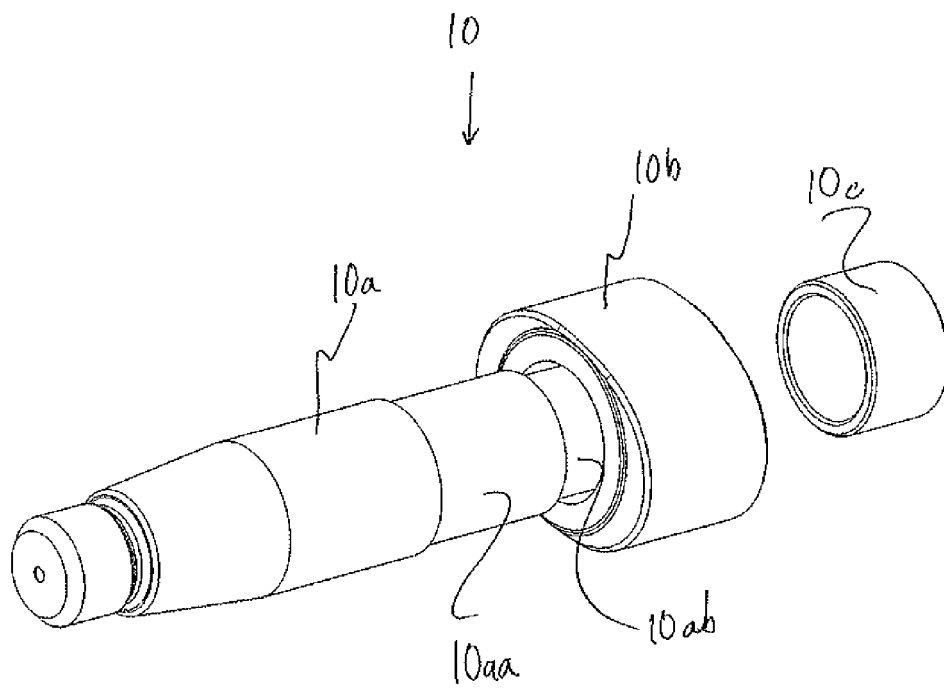


Figure 7

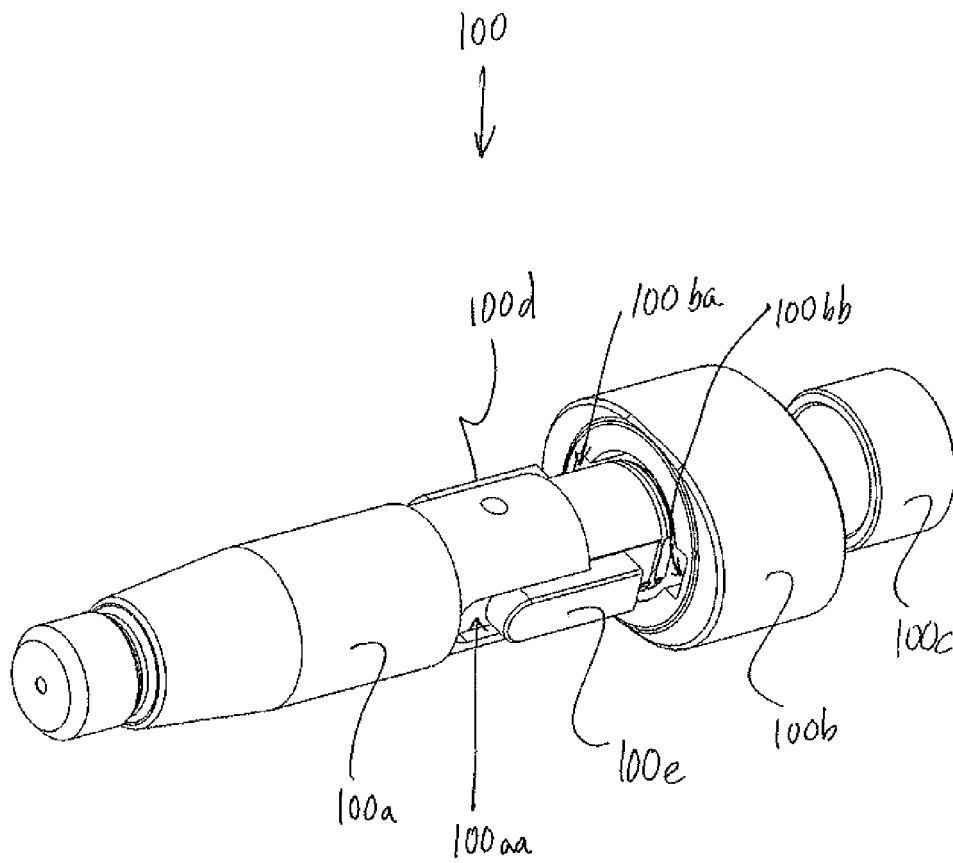


Figure 8



EUROPEAN SEARCH REPORT

Application Number
EP 11 17 6843

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	EP 1 770 274 A1 (DENSO CORP [JP]) 4 April 2007 (2007-04-04) * column 4, paragraph 0015 - column 5, paragraph 0016; figure 1 * -----	1-15	
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Place of search Munich		Date of completion of the search 16 November 2011	Examiner Etschmann, Georg
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 11 17 6843

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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