A fuel pump assembly for use in an engine comprising a pumping plunger (14) which is reciprocable, in use, under the influence of an associated drive arrangement (24, 26) so as to cause pressurisation of fuel within a pumping chamber (22). The drive arrangement includes a shoe (24) and a roller (26) which is cooperable with a driven cam (28) so as to impart reciprocal movement to the shoe (24) as the cam (28) is driven, in use. The roller (26) has a first surface area region (54) having a first surface roughness and a second surface area region (52) having a second surface roughness higher than the first surface roughness and in that static friction between the roller (26) and the cam (28) is larger than static friction between the roller (26) and the shoe (24).
Description

[0001] The invention relates to a pump assembly for use in supplying high pressure fuel to the fuel injection system of a compression ignition internal combustion engine.

[0002] In a known fuel pump for use in a compression ignition internal combustion engine, a plurality of plungers are reciprocable within respective plunger bores so as to pressurise fuel within respective pumping chambers for delivery to the fuel injection system associated with the engine. It is common to provide three plungers which are equi-angularly spaced around a drive shaft. Each plunger is moveable under the influence of a cam drive arrangement to perform a pumping stroke in which fuel is pressurised within its pumping chamber. A plunger return spring effects a plunger return stroke in which the plunger is retracted from the plunger bore.

[0003] The cam drive arrangement includes a common eccentric cam surface, which is co-operative with all three of the plungers to cause reciprocal movement of the plungers within their respective plunger bores in a phased, cyclical manner. Each of the plungers is driven by the cam arrangement via an intermediate drive member. For example, each of the plungers may be coupled to a cylindrical tappet member which serves to drive movement of the associated plunger within its bore. However, pump arrangements of this type can be difficult to assemble. Furthermore, the tappets require a relatively large accommodation space and are relatively expensive components. Parasitic pumping power losses are also an inherent feature of hydraulic tappet operation.

[0004] Our co-pending European patent application, EP 1223334A, describes a multi-plunger fuel pump in which the intermediate drive arrangement for each plunger is a roller and show arrangement (a "roller-shoe" drive arrangement), instead of a tappet drive arrangement. The roller is co-operative with the cam surface of the cam arrangement so as to impart reciprocal movement to the shoe upon rotation of the drive shaft. In turn, each shoe is coupled to a plunger which serves to pressurise fuel within a pump chamber as the cam arrangement is driven. The pump includes three pump assemblies housed within a unitary pump housing.

[0005] A pump housing part in the form of a tubular member is arranged coaxially with the drive shaft and housed within the main pump housing. The tubular member is provided with a plurality of apertures, each of which is shaped to guide reciprocal movement of an associated shoe as the roller rides over the cam surface. The shoe associated with each plunger is of rectangular or square cross section.

[0006] There are two phases of pump operation during rotation of the cam. The filling phase occurs as the plunger is retracted within its bore under the return spring force and the fuel enters the pumping chamber, and the pumping phase occurs as the fuel is forced into the injection system at high pressure (at least 1600 bar). Inlet and outlet valves to control fuel flow to and from the pumping chambers, respectively, are provided in flow passages defined within the main pump housing.

[0007] Such roller-shoe drive arrangements, although an improvement on the tappet arrangement discussed above, can have unacceptable levels of unreliability especially in the filling phase.

[0008] It is an object of the present invention to provide an improved pump assembly for use in supplying high pressure fuel.

[0009] The present invention provides a fuel pump assembly for use in an engine, the fuel pump assembly comprising a pumping plunger which is reciprocable, in use, under the influence of an associated drive arrangement so as to cause pressurisation of fuel within a pumping chamber. The drive arrangement includes a shoe and a roller which is co-operative with a driven cam so as to impart reciprocal movement to the shoe as the cam is driven, in use. The pump assembly is characterised in that the roller has a first surface area region having a first surface roughness and a second surface area region having a second surface roughness higher than the first surface roughness. The shoe is adapted so that the static friction between the roller and the cam is larger than the static friction between the roller and the shoe. In this way, the risk of the roller sliding across the cam surface is therefore reduced. Advantageously, the roller can reach its critical speed of rotation quicker compared with a roller having uniform surface roughness. Also, the roller rotation at or above this critical speed is maintained over a range of engine operating conditions, particularly during the filling phase.

[0010] Preferably, the first surface area region and the second surface area region are provided on an outer surface of the roller. Advantageously, the shoe has a bearing surface for the roller, the bearing surface being shaped so that, in use, the first surface area region does not contact the bearing surface. This, therefore, minimises wear between the roller and the shoe. Conveniently, the bearing surface is shaped to have a recess that corresponds substantially with the first surface area region of the roller.

[0011] Preferably, the size of the recess has a width substantially the same or larger than the width of the first surface area region and the first surface area region is a band extending around the roller. In one embodiment the first surface area region is approximately midway along the length of the roller.

[0012] The roller can also have a third surface area region having substantially the same surface roughness as the second surface area region, the second and third surface area regions being positioned either side of the first surface area region, and wherein the surface roughness of the second and third surface area regions is higher than the first surface roughness.

[0013] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:
Figure 1 is a perspective view of a fuel pump assembly in accordance with an embodiment of the present invention.

Figure 2 is a sectional view of the pump assembly in Figure 1.

Figure 3 is a sectional end view of the pump assembly in Figures 1 and 2.

Figure 4 is a sectional end view of a roller and shoe in accordance with the present invention.

Figure 5 is a side view of the roller and shoe of Figure 4, with a portion of the shoe cut away for clarity, and Figure 6 is a perspective view of part of a main pump housing assembly.

[0014] Referring to Figures 1 to 3, there is shown a high pressure fuel pump assembly suitable for use in the fuel injection system of a compression ignition internal combustion engine. In particular, the fuel pump assembly is suitable for use in delivering high pressure fuel to the common rail of a common rail fuel injection system. Many aspects of the fuel pump assembly in Figure 1 are known, and these parts will only be described briefly. The pump assembly includes a main pump housing 10 through which a cam drive shaft 12 of the engine extends along a drive shaft axis extending perpendicularly to the plane of the page. First, second and third pump heads 13a, 13b, 13c respectively are mounted upon the main pump housing 10 at approximately equi-angularly spaced radial locations around the drive shaft axis, with the drive shaft 12 extending through a central through bore 40 provided in the main pump housing 10. Each pump head 13a, 13b, 13c includes a respective pump head housing 18a, 18b, 18c.

[0015] The pump heads 13a, 13b, 13c are substantially identical to one another and, as can be seen most clearly in Figures 2 and 3, the first pump head 13a includes a pumping plunger 14 which is reciprocal within a blind bore 16 to perform a pumping cycle having a pumping stroke (or forward stroke) and a return stroke. The blind bore 16 is defined partly within the pump head housing 18a and partly within a plunger support tube 20 which extends from a lower surface of the pump head housing 18a. The blind end of the bore 16 defines, together with the pump head housing 18a, a pumping chamber 22. Reciprocating movement of the plunger 14 within the bore 16 causes pressurisation of fuel within the pumping chamber 22 during the pumping stroke. The pumping plunger 14 is driven axially within the bore 16, in use, under the influence of a drive arrangement including a shoe 24 and an associated roller 26.

[0016] The roller 26 and shoe 24 are shown in further detail in Figures 4 and 5. The roller 26 is substantially cylindrical, having a length extending along a longitudinal axis and having a substantially circular cross-section transverse to its length. The shoe 24 has a length extending along a longitudinal axis which is substantially the same as the length of the roller. The shoe 24 is substantially rectangular in cross-section transverse to its length. In an alternative embodiment, a shoe of square section may also be used.

[0017] The shoe 24 has a bearing surface 49 which is recessed and shaped to receive a longitudinal portion of the roller 26 in use. The cross-sectional profile or shape of the bearing surface 49 is substantially semi-circular and has a slightly larger diameter than the diameter of the circular cross-section of the roller 26 so that the roller 26 is rotatable about its longitudinal axis in the bearing surface of the shoe 24.

[0018] The roller 26 is also co-operative with a cam surface 27 of a cam member 28 which is carried by the drive shaft 12. As the shaft 12 rotates in use, the roller 26 rides over the cam surface 27 imparting movement to the shoe 24 and, hence, imparting axial movement (i.e. along the main plunger axis) to the pumping plunger 14 to drive the pumping stroke.

[0019] The fuel pump assembly of the present invention differs from known pumps in the configuration of the shoe and roller arrangement. In known fuel pumps of the aforementioned type, the shoe and roller are arranged in a similar manner but the surface roughness of the roller outer face and the co-operative bearing surface of the shoe are selected to be substantially smooth.

[0020] The inventors have now made the surprising discovery that it is advantageous to select the surface roughness of the roller 26 so that it varies along the length of the roller 26.

[0021] It will be appreciated that, in use, the roller 26 must rotate when assembled in the shoe 24 to enable it to ride or roll over the cam surface 27. If the roller 26 rotation were to slow down relative to the cam or cease altogether, which may happen under certain operating conditions, the cam member 28 would slide across the stationary roller 26 resulting in increased wear between the components and reducing the life of the engine.

[0022] Although the roller/shoe and the roller/cam interfaces are both immersed in fuel, it is the roller/cam interface that is lubricated in the elastohydrodynamic regime. The hydrodynamic lubrication regime operates at the roller/shoe interface once the roller reaches a sufficient rotational speed, which is when the roller-shoe drive arrangement is at its most efficient. It is important for the roller to achieve this sufficient speed as soon as possible after engine start-up and to maintain at least this speed under all operating conditions (e.g. over all engine speeds, over all rail pressures) in order to prevent sliding between the cam and the roller. By preventing sliding between the components, wear is kept to a minimum and pump life is prolonged.

[0023] For the roller to rotate and roll across the cam surface, the adhesive/static frictional force between the roller and the cam must be greater than the resistive force
between the roller and the shoe. In some situations, such as at engine start-up, the static frictional force between the roller and the cam is less than the resistive force between the roller and the shoe. As a result, the roller does not rotate so that the cam slides across the stationary roller resulting in increased wear between the components.

The adhesive or static force between the roller and the cam is affected by the contact pressure between the surfaces. During the pumping phase, the contact pressure is high due to the force exerted on the plunger by fuel pressure within the pumping chamber. However, during the filling phase the contact pressure is low as the only force is that provided by the return spring which serves to urge the shoe and the roller towards the cam such that the roller maintains contact with the cam surface throughout a complete cam rotation. It is under these conditions that the roller may reduce its rotational speed and in extreme cases stop rotating altogether. Therefore, for maximum efficiency, it is desirable to ensure that the roller continues to rotate during both the filling and the pumping phases.

To ensure that the roller 26 continues to rotate in the shoe 24 during use, a region of the outer surface 50 of the roller 26 is provided with a higher surface roughness than adjoining regions of the outer surface. This area of higher surface roughness extends as a band 54 around the circular outer surface 50 of the roller 26, and over a region approximately midway along the length of the roller 26. Therefore, the outer surface 50 of the roller can be considered to comprise three regions or bands across the roller 26; a first normal surface roughness band 52, a higher surface roughness band 54, and a second normal surface roughness band 52 arranged one next to the other. The higher surface roughness band 54 on the roller 26 results in increased static friction between the roller 26 and the cam member 28 as the roller 26 rolls over the cam surface 27.

To ensure that the higher surface roughness band 54 of the roller 26 does not contact the bearing surface 49 of the shoe 24, the shoe 24 comprises a recess or relief 56 in the bearing surface 49. The recess 56 has a size and shape corresponding to the size and shape of the higher surface roughness region 54 or, alternatively, the size of the recess 56 can be larger than the higher surface roughness region 54. In this way, only the normal surface roughness regions 52 of the roller 26 contact the bearing surface 49 of the shoe 24. There is no modification of the cam surface 27 and so all three regions 52, 54 of the roller surface contact the cam surface 27 (i.e. the roller 26 contacts the cam surface 27 along the entire roller length).

By virtue of the higher surface roughness region 54 on the roller 26, the adhesive/static frictional force between the roller 26 and the cam surface 27 is greater than the resistive force between the roller 26 and the shoe 24. The benefits of this are twofold. Firstly, upon engine start-up, the roller 26 reaches its critical speed (that speed at which hydrodynamic lubrication occurs at the roller/shoe interface) over a shorter time-scale than for a roller of uniform surface roughness. Secondly, roller rotation at or above this critical speed is maintained over a range of engine operating conditions (engine speed or common rail pressure). In particular, during filling when the load on the cam is relatively low and the risk of the roller sliding, relative to the cam, would be higher, the invention ensures that the cam/roller friction is higher than the roller/shoe friction. The risk of the roller 26 sliding across the cam surface during the filling phase is therefore reduced.

The higher surface roughness region 54 does not have to be positioned midway along the length of the roller 26 but can be positioned at any point along the length, as long as a corresponding recess 56 is provided in the bearing surface 49 of the shoe 24 so that the higher surface roughness region 54 does not contact the shoe 24. As a further alternative, more than one higher surface roughness region can be provided on the roller, each region having a corresponding recess in the shoe.

In a further alternative embodiment, higher surface roughness regions may be provided at the outer ends of the roller 26 with the centre or middle region being of normal surface roughness. This may be beneficial as the load distribution across the roller 26 is at a maximum in the middle region and this embodiment the roller/shoe bearing interface is maintained in this region.

It will be appreciated that the shoe and roller arrangement of each pump head 13a, 13b, 13c co-operates with the cam surface 27, which is thus common to all three pump heads. As the drive shaft 12 rotates, the rollers co-operate with the common cam surface 27 to cause reciprocating motion of the shoes in a phased, cyclic manner depending on the cam surface profile, as would be understood by a person skilled in this technical field.

For the sake of completeness, there now follows a description of one way in which the shoes may be mounted and guided within the assembly. Referring to Figure 6, a radially extending opening 32 in the form of a radially extending bore is provided in the main pump housing 10. The opening 32 defines an internal surface of substantially cylindrical form, and a first, hollow insert 30a, which is associated with the first pump head 13a, is located within the cylindrical opening 32 so as to be coaxial with the bore 16. The insert 30a has an outer surface of substantially cylindrical form, which corresponds to the shaping of the internal surface of the opening 32 in the main pump housing 10. The internal surface of the insert 30a defines a substantially rectangular cross section (in a plane perpendicular to the axis of movement of the plunger 14 and the shoe 24). The internal surface of the insert 30a therefore defines first and second pairs of substantially parallel facing walls 34, 36, which define a guide path of appropriate form for the rectangular section shoe 24 as it reciprocates, in use. The facing internal surfaces 34 of the first pair have a smaller length, along
an axis perpendicular to the plunger axis, than the facing internal surfaces 36 of the second pair. The insert 30a is also formed so that the first pair of internal surfaces 34 have a longer length, along the direction of the plunger axis, than the second pair of internal surfaces 36, and thus upper end regions 130 of the insert 30a are of increased axial height.

[0032] It will be appreciated that although the cross section of the insert guide path is not exactly rectangular (e.g. due to interconnecting corner regions 230 being of curved form - as shown in Figure 6), a guide path of substantially rectangular cross section is defined to provide an adequate guiding surface for the generally rectangular cross section of the shoe 24.

[0033] The second and third pump heads 13b, 13c are also provided with similar inserts 30b, 30c, respectively, each of the inserts 30b, 30c being received within a correspondingly shaped radial opening or bore (such as 32) in the main pump housing 10. Each of first, second and third inserts 30a, 30b, 30c is arranged such that a radially inner end thereof opens into a main axial bore 38 provided in the main pump housing 10 (as can be seen in Figure 3).

[0034] The insert 30a also defines a spring space 74 located above the shoe 24 (in the orientation shown), within which a return spring 84 is located. The return spring 84 serves to urge the shoe 24 and the roller 26 in a radially inward direction such that the roller 26 maintains contact with the cam surface 27 throughout a complete rotation of the drive shaft 12. The force due to the return spring 84 is aided by the force due to fuel pressure within the pumping chamber 22 which acts on the pumping plunger 14 to provide a return force which serves to urge the pumping plunger 14 outwardly from the bore 16 to perform the return stroke. It will be appreciated that this only occurs if the pump is operating at its maximum displacement and, hence, at maximum filling.

[0035] Although the invention has been described for use in a multi-plunger pump, it will be appreciated that the roller/shoe arrangement may equally be employed in a single plunger pump. In either a multi-plunger pump or a single plunger embodiment, the pump head within which the plunger reciprocates may be a separate part from the main pump housing (as described previously), or alternatively may form an integral part of the main pump housing.

Claims

1. A fuel pump assembly for use in an engine, the fuel pump assembly comprising:

   a pumping plunger (14) which is reciprocable, in use, under the influence of an associated drive arrangement (24, 26) so as to cause pressurisation of fuel within a pumping chamber (22), the drive arrangement including a shoe (24) and a roller (26) which is cooperable with a driven cam (28) so as to impart reciprocal movement to the shoe (24) as the cam (28) is driven, in use, characterised in that the roller (26) has a first surface area region (54) having a first surface roughness and a second surface area region (52) having a second surface roughness higher than the first surface roughness and in that static friction between the roller (26) and the cam (28) is larger than static friction between the roller (26) and the shoe (24).

2. A fuel pump as claimed as in claim 1, wherein the first surface area region (54) and the second surface area region (52) are provided on an outer surface (50) of the roller (26).

3. A fuel pump assembly as claimed in claim 1 or claim 2, wherein the shoe (24) has a bearing surface (49) for the roller (26), the bearing surface (49) being shaped so that, in use, the first surface area region (54) does not contact the bearing surface (49).

4. A fuel pump assembly as claimed in claim 3, wherein the bearing surface (49) is shaped to have a recess (56) that corresponds substantially with the first surface area region (54) of the roller (26).

5. A fuel pump assembly as claimed in claim 4, wherein the size of the recess (56) has a width substantially the same or larger than the width of the first surface area region (54).

6. A fuel pump assembly as claimed any preceding claim, wherein the first surface area region (54) is a band extending around the roller (26).

7. A fuel pump assembly as claimed in any preceding claim, wherein the roller (26) has a third surface area region (52) having substantially the same surface roughness as the second surface area region (52), the second and third surface area regions (52) being positioned either side of the first surface area region (54).

8. A fuel pump assembly as claimed in claim 7, wherein the surface roughness of both the second and third surface area regions (52) is higher than the first surface roughness.

9. A fuel pump assembly as claimed in claim 7 or 8, wherein the first surface area region is approximately midway along the length of the roller (26).
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The present search report has been drawn up for all claims

Place of search: Munich
Date of completion of the search: 15 January 2007
Examiner: Godrie, Pierre

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