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(54) **Fuel pressurizing plunger assembly for a compression ignition engine**

Kraftstoffdruckerzeugende Kolbenanordnung für eine druckgezündete Brennkraftmaschine

Arrangement de piston mettant du combustible sous pression pour un moteur à allumage par compression

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Description

[0001] The present invention is directed generally toward a fuel pressurizing plunger assembly for a compression ignition engine (Diesel engine) fuel injector operable with Diesel fuel that may contain abrading particles and lubricity lowering contaminants, and particularly to a fuel pressurizing plunger assembly with the features of the precharacterizing part of claim 1.

[0002] Fuel injector plungers are required to operate under extremely adverse environmental conditions in a fuel injector assembly. With a mechanical drive train, heavy mechanical loads are applied to the plunger in both axial and tangential directions. The plunger must reciprocate within a bore in the injector body that is often distorted so the original diametral clearance is not maintained, and the plunger is forced against the bore wall during injector operation, resulting in scuffing. Additionally, low quality and contaminated fuels contribute to the creation of an adverse plunger operating environment.

[0003] The plunger material has been modified throughout the years in an effort to make a plunger that is both scuff-resistant and wear-resistant and capable of functioning as required under the adverse conditions of the fuel injector environment. However, third body debris interferes with efficient injector function. Third body debris includes particles harder than the plunger or injector body bore which are not intended to be present within the injector. These particles become embedded into the plunger surface and ultimately cause the plunger and body to be wedged together so that the plunger cannot reciprocate in the injector body bore and becomes friction welded. The reduction of fuel lubricity, which could be caused by water contamination of the fuel, and may be a characteristic of some alternative fuels, is also a factor contributing to the friction welding of the plunger and injector body together. Injector operation is, of course, prevented if this occurs.

[0004] The types of fuels increasingly used in Diesel engines, particularly fuels with low lubricity, alternative fuels and fuels which may be contaminated with water, require a scuff-resistant fuel injector plunger to maintain efficient engine operation. The prior art plunger assembly defining the pre-characterizing part of claim 1 (JP - A - 60 104765) addresses those problems with a plunger assembly with a plunger formed of a scuff-resistant, wear-resistant ceramic material running in an axial bore of a body portion that is made of steel. The abrasion resistance of ceramics is said to be an advantage in the particular surroundings.

[0005] With a mechanical drive train heavy mechanical loads on the plunger in both axial and tangential directions result in additional requirements for the diametral clearance of the plunger within the bore in the injector body.

[0006] In view of the above it is the object of the present invention to provide a fuel pressurizing plunger assembly for a compression ignition engine (Diesel en-

gine) fuel injector capable of operating efficiently in the presence of high axial and tangential loads on the plunger in view of fuel used that may contain abrading particles and lubricity lowering contaminants.

[0007] Above object is achieved by providing a fuel pressurizing plunger assembly with the features of the pre-characterizing part of claim 1 in combination with the features of the characterizing part of claim 1. The plunger used is wear- and scuff-resistant and maintains an optimum diametral clearance so that it does not stick during fuel injector operation even under adverse engine operating conditions. The injector plunger is formed from a ceramic material having a thermal expansion coefficient sufficiently correlated to the thermal expansion coefficient of the fuel injector body to provide optimum operating clearance between the plunger and injector body during engine operation while preventing fuel leakage around the plunger. Achieving the optimum fuel leakage around the plunger during engine operation is critical. Instead of ceramics with low thermal expansion which allow excessive leakage, high thermal expansion ceramics are capable of maintaining fuel leakage within acceptable parameters.

[0008] Further improvements of the fuel pressurizing plunger assembly of the invention may be obtained from the dependent claims. Further objects and advantages will be apparent from the following description and drawings.

[0009] In the drawings

Fig. 1 is a schematic cross-sectional view of a fuel injector assembly in a Diesel engine incorporating a scuff-resistant anti-stick plunger of the present invention; and

Fig. 2 presents graphically the dimensions of the injector body bore and plunger of the present invention for different materials at different temperatures.

[0010] The plunger in the fuel pressurizing plunger assembly of the invention is a means for causing a controlled volume of fuel to be injected from the fuel injector. In this context it is influencing the timing of the fuel injection. Only in a preferred embodiment it is to be understood as a timing plunger in a more narrow sense, i. e. a separate intermediate plunger in a multiplunger-arrangement controlling a timing chamber. Moreover, the fuel injector assembly can well be a unit fuel injector as well as an in-line fuel injector.

[0011] Fuel injector plunger scuffing and sticking is one cause of high injector RPH (repairs per hundred). High warranty costs may result from the replacement of failed and inoperable plungers. The fuel injector body plunger assembly of the present invention provides a reliable wear-resistant plunger that is free from sticking and scuffing, even when exposed to extremely abusive engine operating conditions. Consequently, the present

invention effectively lowers both the injector RPH and warranty costs occasioned by failed and inoperable plungers.

[0012] Referring to the drawings, Fig. 1 illustrates, in cross section, an open nozzle unit fuel injector 10 with a plunger 12. This type of fuel injector includes a body 14 and an injector nozzle 16. The injector nozzle 16 and the body 14 are axially aligned and held together by a retainer 18. An axial bore 20 extends throughout the length of the body 14. A plurality of spaced injection orifices 22 in the nozzle 16 is provided at the injector cup terminus to optimize fuel injection.

[0013] The injector 10 includes a plunger 12 that reciprocates axially within the injector along with a link 24 that is engaged by one end of a rocker lever 26. The other end of the rocker lever 26 is drivingly connected to the camshaft 28 via a pushtube 30. The rocker lever 26 typically applies both axial and tangential loads to the plunger 12 during engine operation. Arrow (A) represents the axial load applied to the plunger 12 by the rocker lever 26. Arrow (B) represents the tangential or side load applied to the plunger 12 by the rocker lever 26. The axial load applied by the rocker lever 26 to the plunger 12 as it reciprocates in the injector body 14 can be elevated to as high as 10,67 kN (2400 pounds). In addition to these axial and tangential loads, pressures as high as 1690 bar (24,500 psi) are generated by the plunger's downward stroke as it travels toward the injector nozzle 16. This results in a load of 1690 bar (24,500 psi) acting on the plunger 12 in an upward axial direction, away from the nozzle 16 and toward the rocker lever 26, as shown by arrow (C).

[0014] The ceramic plunger 12 is sized relative to the injector body bore 20 to provide a diametral clearance of 1,93 to 3,25 μm (76-128 millionths of an inch). The diametral clearance can be less than that of known plunger designs due to differences in thermal expansion between the currently available stainless steel plunger and the ceramic plunger 12. The aforementioned loads on the plunger 12 and the clamp load on the injector body 14 often distort the axial bore, which decreases the diametral clearance. The rocker lever generated side load (arrow B) then forces the plunger 12 against the wall of the body bore 20. Plunger scuffing and wear occur under such circumstances. The presence of the third body debris in the injector body bore compounds the plunger problems under these loads.

[0015] The severity of the plunger operating environment is further increased by low sulfur and low lubricity fuels and fuels contaminated by water. A ceramic plunger presents many advantages. The kinds of ceramic materials evaluated for use as plungers are much harder than the materials currently used for either the plunger or the injector body. Moreover, the ceramic material has a low reactivity and a low affinity to weld with petroleum lubricated metal counterfaces. However, the optimum surface finish must be created for the best sliding wear performance.

[0016] Plungers made from high thermal expansion ceramics, including zirconia, alumina-zirconia and alumina have been demonstrated to show significantly better scuffing resistance than plungers made from metal. Although other ceramics, most notably silicon nitride, also display superior scuff resistance, only high thermal expansion ceramics have been found to be suitable for use in forming unit fuel injector plungers. The preferred ceramic materials for use in forming fuel injector plungers are those with a thermal expansion coefficient greater than $6 \times 10^{-6}/^{\circ}\text{C}$ and a hardness greater than 800 kg/mm². The thermal expansion coefficient of the ceramic selected for the plunger should match as closely as possible that of the metal forming the injector body.

[0017] Fig. 2 compares the diameters of the injector body bore 20 (Fig. 1) with the diameters of a plunger currently in use and two ceramic plungers with differing diametral clearances. Curve A represents the diameter of the injector body bore over the range of temperatures studied. Curve B shows the changes in plunger diameter when the plunger 12 is formed from stainless steel. The diametral clearance between the stainless steel plunger and the injector bore in the assembly tested was 5,0 μm . Curves C and D demonstrate diametral changes in plunger diameter for two ceramic plungers at different clearances. The diametral clearance between the plunger and the bore for the assembly represented by curve C was 2,5 μm , while the clearance at the curve D plunger assembly was 5,0 μm . Fig. 2 clearly demonstrates that a ceramic plunger in accordance with the present invention can have a smaller diametral clearance in the injector bore than a stainless steel plunger and still function effectively in the presence of the loads applied to the plunger during engine operation.

Claims

1. A fuel pressurizing plunger assembly for a compression ignition engine (Diesel engine) fuel injector (10) operable with Diesel fuel that may contain abrading particles and lubricity lowering contaminants,

wherein the plunger assembly includes

an axial bore (20) located within a body portion (14) of the fuel injector (10), the axial bore (20) defined by an inner surface of the body portion (14) having a predetermined bore diameter, said body portion (14) being formed of a metal having a predetermined thermal expansion coefficient,

a plunger (12) mounted for reciprocating axial movement within said axial bore (20), this plunger (12) being formed of a scuff resistant, wear-resistant ceramic material, and

a drive train means for applying a periodic pressurization force to the plunger (12) for causing a controlled volume of fuel to be injected from the fuel injector (10) into an engine cylinder at desired intervals during engine operation, this pressurization force including a substantial side loading force which tends to bias the external surface of the plunger (12) into contact with the surrounding inner surface of the axial bore (20),

wherein the plunger (12) has a predetermined plunger diameter slightly less than the predetermined bore diameter to form a diametral clearance between the axial bore (20) and the plunger (12),

characterized in that

the diametral clearance between the plunger (12) and the axial bore (20) is 1,93 to 3,25 μm (76 to 128 millionths of an inch),
the ceramic material of the plunger (12) has a low reactivity and a low affinity to weld with the fuel lubricated inner surface of the axial bore (20) and a thermal expansion coefficient which is substantially the same as the thermal expansion coefficient of the metal forming the body portion (14),
the wear-resistant ceramic material of the plunger (12) has a thermal expansion coefficient greater than $6 \cdot 10^{-6}/^{\circ}\text{C}$ and a hardness greater than 800 kg/mm².

2. Plunger assembly according to claim 1, characterized in that the ceramic material of the plunger (12) is selected from the group consisting of zirconia, alumina-zirconia and alumina ceramics.
3. Plunger assembly according to claim 1 or 2, characterized in that the plunger (12) is operably positioned axially within the fuel injector body portion (14) between a link (24) connected to the drive train and a nozzle end of the unit fuel injector (10).
4. Plunger assembly according to claim 3, characterized in that the drive train includes a rocker lever (26), a push tube (30) operatively extending from a camshaft (28) to one side of the rocker lever (26), the link (24) operatively extending from the other side of the rocker lever (26) to the plunger (12) to cause the plunger (12) to reciprocate as the camshaft (28) rotates, whereby a high axial force is imposed on the plunger (12) by the link (24) as the plunger (12) is advanced toward the injector nozzle and a side force is simultaneously imposed on the plunger (12) by the link (24) which biases the plunger (12) toward the inner wall of the axial bore (20).

5. Plunger assembly according to any one of the preceding claims, characterized in that the plunger (12) is a timing plunger.

Patentansprüche

1. Kraftstoff unter Druck setzender Plungerkolbenaufbau für einen Kraftstoffinjektor (10) eines druckgezündeten Motors (Dieselmotors), wobei der Kraftstoffinjektor mit Dieselmotorkraftstoff betreibbar ist, der abscheuernde Partikel und die Schmierfähigkeit senkende Verschmutzungen enthalten kann,

wobei der Plungerkolbenaufbau aufweist

eine axiale Bohrung (20), die innerhalb eines Körperabschnitts (14) des Kraftstoffinjektors (10) angeordnet ist, wobei die axiale Bohrung (20) eine innere Oberfläche des Körperabschnitts (14) mit einem vorbestimmten Bohrungsdurchmesser definiert, wobei der Körperabschnitt (14) aus einem Metall mit einem vorbestimmten Wärmeausdehnungskoeffizienten gebildet ist,

einen Plungerkolben (12), der zur hin- und hergehenden Bewegung innerhalb der axialen Bohrung (20) eingebaut ist, wobei dieser Plungerkolben (12) aus einem abriebfesten, verschleißresistenten Keramikmaterial gebildet ist, und

ein Antriebszugmittel zur Ausübung einer periodischen, den Druck erzeugenden Kraft auf den Plungerkolben (12), wodurch ein gesteuertes Volumen an Kraftstoff aus dem Kraftstoffinjektor (10) in einen Motorzylinder an bzw. in gewünschten Intervallen während des Motorbetriebs eingespritzt wird, wobei diese druckzeugende Kraft eine wesentliche Seitenbelastungskraft umfaßt, die dazu neigt, die äußere Oberfläche des Plungerkolbens (12) in Kontakt bzw. Anlage mit der umgebenden inneren Oberfläche der axialen Bohrung (20) zu drücken,

wobei der Plungerkolben (12) einen vorbestimmten Plungerkolbendurchmesser aufweist, der etwas geringer als der vorbestimmte Bohrungsdurchmesser ist, um ein Durchmesserspiel zwischen der axialen Bohrung (20) und dem Plungerkolben (12) zu bilden,

dadurch gekennzeichnet, daß

das Durchmesserspiel zwischen dem Plungerkolben (12) und der axialen Bohrung (20) 1,93

bis 3,25 µm (76-128 Millionstel eines Inch) beträgt,

das Keramikmaterial des Plungerkolbens (12) eine niedrige Reaktivität bzw. Reaktionsbereitschaft und eine geringe Affinität, mit der Kraftstoff geschmierten inneren Oberfläche der axialen Bohrung (20) zu verschweißen, und einen Wärmeausdehnungskoeffizienten, der im wesentlichen dem Wärmeausdehnungskoeffizienten des den Körperabschnitt (14) bildenden Metalls entspricht, aufweist, das verschleißresistente Keramikmaterial des Plungerkolbens (12) besitzt einen Wärmeausdehnungskoeffizienten, der größer als $6 \cdot 10^{-6}/^{\circ}\text{C}$ ist, und eine Härte größer als 800 kg/mm² aufweist.

2. Plungerkolbenaufbau nach Anspruch 1, dadurch gekennzeichnet, daß das keramische Material des Plungerkolbens (12) aus der Gruppe, bestehend aus Zirkon(dioxyd)-, Aluminiumoxyd-Zirkon(dioxyd)- und Aluminiumoxyd-Keramiken, ausgewählt ist. 20
3. Plungerkolbenaufbau nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Plungerkolben (12) axial betreibbar in dem Kraftstoffinjektorkörperabschnitt (14) zwischen einer Verbindung (24), die mit dem Antriebszug verbunden ist, und einem Düsenende der Kraftstoffinjektoreinheit (10) angeordnet ist. 25 30
4. Plungerkolbenaufbau nach Anspruch 3, dadurch gekennzeichnet, daß der Antriebszug einen Kipphebel (26), eine Stoß- bzw. Stößelstange (30) aufweist, die sich betätigungsmäßig von einer Nockenwelle (28) zu einer Seite des Kipphebels (26) erstreckt, und die Verbindung (24) aufweist, die sich betätigungsmäßig von dem anderen Ende des Kipphebels (26) zu dem Plungerkolben (12) erstreckt, um den Plungerkolben (12) hin und her zu bewegen, wenn die Nockenwelle (28) rotiert, wobei eine hohe axiale Kraft auf den Plungerkolben (12) durch die Verbindung (24) ausgeübt wird, wenn der Plungerkolben (12) zur Einspritzdüse vorgeschoben wird, und gleichzeitig eine Seitenkraft auf den Plungerkolben (12) durch die Verbindung (24) ausgeübt wird, welche den Plungerkolben (12) zu der inneren Wand der axialen Bohrung (20) drückt. 35 40 45
5. Plungerkolbenaufbau nach einem der voranstehenden Ansprüche, dadurch gekennzeichnet, daß der Plungerkolben (12) ein Zeitsteuerplungerkolben ist. 50

Revendications

1. Arrangement de piston de mise sous pression de combustible pour un injecteur de combustible (10) 55

de moteur à allumage par compression (moteur Diesel) pouvant fonctionner avec un combustible Diesel qui peut contenir des particules abrasives et des contaminants réducteurs du niveau de lubrification,

dans lequel l'arrangement de piston inclut un alésage axial (20) situé dans une partie de corps (14) de l'injecteur de combustible (10), l'alésage axial (20) défini par une surface interne de la partie de corps (14) présentant un diamètre d'alésage prédéterminé, ladite partie de corps (14) étant formée d'un métal présentant un coefficient de dilatation thermique prédéterminé;

un piston (12) monté pour un mouvement axial de va-et-vient à l'intérieur dudit alésage axial (20), ce piston (12) étant formé d'un matériau céramique résistant aux éraflures et résistant à l'usure, et un moyen de transmission pour appliquer une force de mise sous pression périodique sur le piston (12) pour amener un volume contrôlé de combustible de l'injecteur de combustible (10) dans un cylindre de moteur à des intervalles souhaités pendant le fonctionnement du moteur, cette force de mise sous pression incluant une force de charge latérale significative qui a tendance à incliner la surface externe du piston (12) en contact avec la surface interne environnante de l'alésage axial (20), dans lequel le piston (12) présente un diamètre de piston prédéterminé légèrement inférieur au diamètre d'alésage prédéterminé pour former un espacement diamétral entre l'alésage axial (20) et le piston (12),

caractérisé en ce que

l'espacement diamétral entre le piston (12) et l'alésage axial (20) est compris entre 1,93 et 3,25 µm (76 à 128 millièmes de pouce), le matériau céramique du piston (12) présente une faible réactivité et une faible affinité au soudage avec la surface interne lubrifiée par combustible de l'alésage axial (20) et un coefficient de dilatation thermique qui est pratiquement identique au coefficient de dilatation thermique du métal formant la partie de corps (14), le matériau céramique résistant à l'usure du piston (12) présente un coefficient de dilatation thermique supérieur à $6 \cdot 10^{-6}/^{\circ}\text{C}$ et une dureté supérieure à 800 kg/mm².

2. Arrangement de piston suivant la revendication 1, caractérisé en ce que le matériau céramique du piston (12) est sélectionné parmi le groupe constitué des céramiques de zircone, d'alumine-zircone et d'alumine.

3. Arrangement de piston suivant la revendication 1 ou 2, caractérisé en ce que le piston (12) est, en fonctionnement, positionné de manière axiale à l'intérieur de la partie de corps d'injecteur de combustible (14) entre une bielle (24) reliée à la transmission et une extrémité de gicleur de l'injecteur de combustible d'unité (10). 5
4. Arrangement de piston suivant la revendication 3, caractérisé en ce que la transmission inclut un levier de culbuteur (26), un tube pousseur (30) s'étendant, en fonctionnement, d'un arbre à came (28) à un côté du levier culbuteur (26), la bielle (24) s'étendant, en fonctionnement, de l'autre côté du levier culbuteur (26) au piston (12) pour amener le piston (12) à aller et venir tandis que l'arbre à cames (28) tourne, par lequel une force axiale élevée est exercée sur le piston (12) par la bielle (24) tandis que le piston (12) est avancé en direction du gicleur d'injecteur et une force latérale est simultanément exercée sur le piston (12) par la bielle (24) qui incline le piston (12) en direction de la paroi interne de l'alésage axial (20). 10 15 20
5. Arrangement de piston suivant l'une quelconque des revendications précédentes, caractérisé en ce que le piston (12) est un piston de distribution. 25

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FIG. 1



