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(54) **A method of minimizing deposits in a fuel injector**

Verfahren für die Reduzierung von Ablagerungen in einem Kraftstoffinjektor

Procédé pour minimaliser les dépôts dans un injecteur de combustible

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EP 1 505 342 B1

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Description

[0001] This invention relates to a method of minimising deposits in a fuel injector, in particular for high pressure fuel injector valves.

[0002] US 5,921,473 discloses a fuel injector having a spherical valve-closure member and valve seat and US 4,830,286 discloses an electromagnetically actuatable valve.

[0003] Much effort has been expended in the design of fuel injectors to achieve a specific flow velocity and desired spray quality. Different stages of a fuel injector valve seat and injection hole are constructed with carefully chosen geometries to achieve this. However, despite all these efforts, the engine performance and emissions are degraded with time due to build up of deposits in the fuel injector and particularly at the fuel injector tip, from exposure to high temperature gases from the combustion chamber.

[0004] Various proposals have been made to deal with deposit build-up. US5941208 describes a method of removing coke deposits from a fuel injector nozzle by changing from compression stroke injection to suction stroke injection for a period, so that the deposits are thermally decomposed. EP-1045202 describes a fuel injector in which an air stream is split into two airstreams interspersed with two fuel streams and also provided with air jets to ensure improved fuel-air mixing, and hence clean burning, to prevent coke formation. However, these proposals increase the complexity of the construction and operation of the injectors.

[0005] US 6,334,434 B1 discloses a fuel injector with a sharp edge in col. 6, 1 39-42 and speculates that fuel deposit are reduced due to cavitation if the included angle is increased to approximately 95° to 100°. However this document mentions in the same passage that as a as a disadvantage flow stability decreases. It is therefore the objective of the present invention to increase flow stability. This objective is achieved by the measures taken in accordance with the independent claims. In accordance with a first aspect of the present invention, a method of minimising deposits in a fuel injector comprises providing a fuel flow passage about a central axis of the fuel injector, the passage including a valve seat and a needle orifice; setting the valve seat to be inclined at a first angle to the central axis; providing a first volume between the valve seat and the needle orifice; and a first edge between the valve seat and the first volume; wherein the first volume is chosen such that fuel flow remains substantially laminar as it passes over the first edge; providing an annulus at the base of the first volume, radially outwardly of the needle orifice, wherein the annulus is in a plane perpendicular to the central axis and a second edge formed between the annulus and the needle orifice; wherein fluid passing over the second edge is caused to cavitate, such that deposits in the needle orifice are substantially removed.

[0006] The present invention provides a solution to the problems of deposit build up which does not rely on complex methods of operation or construction.

[0007] The first volume could be cylindrical with side walls parallel to the central axis, but this can result in deposits collecting in the corners over time, so preferably a wall of the first volume is inclined at a second angle to the central axis.

[0008] Preferably, the first volume comprises a truncated cone.

[0009] Preferably, the first angle is greater than the second angle.

[0010] Typically, the wall of the valve seat is angled at between 45 DEG and 51 DEG to the central axis, but preferably, the first angle is 51 DEG to the central axis.

[0011] The wall of the first volume may be parallel to the central axis, or at any suitable angle that allows laminar flow, but typically, the second angle is in the range of 13 DEG to 17 DEG, but preferably the second angle is 15 DEG.

[0012] An example of a fuel injector and a method of minimising deposits in accordance with the present invention will now be described with reference to the accompanying drawings in which:

> Figure 1 illustrates an example of a conventional fuel injector;
> Figure 2 illustrates an example of a fuel injector adapted to remove deposits during operation;
> Figure 3 shows an example of a fuel injector according to the present invention; and,
> Figure 4 illustrates relative performance of a conventional fuel injector and the fuel injector of the present invention.

[0013] A key parameter influencing rate of deposit formation is surface temperature of the injector tip, so the most straightforward way to control deposits is to maintain the injector tip temperature below the critical deposit forming temperatures, typically around 120°C, depending upon the fuel composition. However, the injector tip temperature is not just a function of injector design, but also affected by amongst others, combustion system design, head design and engine operating parameters. Thus it is difficult to design an injector which remains cool in all applications.

[0014] Another method of preventing deposits is to carefully control the amount of fuel on the tip available to form deposits, through careful control of orifice and tip geometry. The injector tip plays a role in the reaction which forms deposits. Hence the choice of material and surface treatments affect the rate of deposit formation. Another feature is to use inert materials in injector seats.

[0015] If the formation of deposits cannot be prevented, then mechanisms are required to remove them. One method of deposit clean up is to coat the tip surfaces with a material of extremely low surface energy. That way, deposits cannot adhere to the surfaces and are easily washed away by the fuel flow. Alternatively, the injectors could be removed and cleaned with specially designed solvents, but this is unacceptable to the user in terms of cost and inconvenience.

[0016] The present invention relies on a mechanical effect, using cavitation as to dislodge deposits. Cavitation occurs when there is a change in the velocity of a liquid, which causes a change in pressure of the liquid. Cavities form in the liquid and then collapse as they pass into a region of higher pressure. The present invention makes use of this mechanism by which the fuel flow through the fuel injector acts to overcome the problem of deposit formation, rather than using a separate cleaning step. The cavitation is set up by providing a sharp edge at the needle orifice giving the fuel flow a mechanical advantage in breaking away deposits as they form on the tip face.

[0017] Figure 1 illustrates an example of a fuel injector 1 of a conventional type which is effectively a single cone with a hole in the bottom. The included angle of the cone is typically between 90 and 102 degrees, the angle α to the central axis 2 being between 45° and 51°. However, although manufacturing burrs and a high transition cone angle in the needle orifice can produce cavitation, they also reduce production flow yield because the cavitation begins at various stages of needle lift depending on the most minute details of the interface between the transition cone and the orifice hole. As cavitation occurs, the flow through the orifice is reduced due to the vapour content of the fuel. If on a part to part basis, cavitation occurs differently depending on the needle lift, this will introduce a wide variation in dynamic flow of the injectors.

[0018] Fig. 2 illustrates an example of a design of a step cavitating orifice for a fuel injector. A valve seat 3 is provided at an upstream end of the fuel flow, which in this example is positioned at an angle of 51° to the central axis 2. A first edge 4 is formed between the valve seat and a cylindrical volume 5, such that the transition cone of the conventional production zone of Fig. 1 is replaced with a step. At the base of the cylindrical volume is a needle orifice 6 which joins to the volume 5 via a second edge 7. Sudden expansion causes the flow to separate over the first edge 4 and the contraction at the second edge 7 causes the flow to cavitate. The collapse of the cavitation bubbles happens downstream along the needle orifice side, removing deposits. The cavitation relies on the second edge 7 and since the flow contraction is so dramatic, the cavitation does not rely heavily on the condition of that edge. A problem with this design is that there is still variation in flow from part to part, affecting the injector performance.

[0019] Fig. 3 illustrates a flat cavitating orifice in a fuel injector according to the present invention. In the previous step design of Fig. 2, the first and second edges 4, 7 are formed by placement of a cylindrical volume between the sealing cone of the valve seat 3 and the orifice 6. In the flat design of the example of Fig.3, an angled wall 8, at an angle β to the central axis 2 forming a cone, replaces the vertical wall of the cylinder present in the stepped design. A first edge 9 is formed between the top of the cone 8 and the bottom of the valve seat 3. At the base of the cone there is an annulus 10, in a plane perpendicular to the central axis 2 and a sharp, second edge 11 at the entrance to the orifice 6. The annulus has a maximum diameter which reaches, but does not encroach on the sealing diameter.

[0020] The fuel injector has the feature that the fuel flow passage induces cavitation as soon as possible, as the flow accelerates through it. Furthermore, the present invention gives a manufacturable design that will induce cavitation in a repeatable way. The principle behind this design is to reduce or eliminate the separation off the first edge by making the expansion less sudden, while still providing the second edge at the entrance to the needle orifice. As in the step design, the second edge provides a sudden contraction to induce cavitation. By reducing the amount of flow separation from the first edge, there will be less variation in flow from part to part.

[0021] Prototype injectors with angle β equal to 15° +/- 2° have been manufactured and tested. The results are shown in Fig. 4. Each point represents percentage change in injector fuel flow at the end of a 6 hour test. The tests are performed at different engine conditions to give the respective injector tip temperatures. The baseline injectors shift lean due to deposit formation and the step injectors have a slight rich shift due to a mechanical durability shift. The results of Fig. 4 indicate that the flat cavitating orifice of Fig. 3 is effective at removing deposits as they form, as the optimum result is to have no change in fuel flow. As the orifice plugs with deposits the flow will increase. The percentage change for the baseline example indicates a noticeably greater reduction in flow than in the present invention.

Claims

1. A method of minimising deposits in a fuel injector (1), the method comprising providing a fuel flow passage about a central axis (2) of the fuel injector (1), the passage including a valve seat (3) and a needle orifice (6); setting the valve seat (3) to be inclined at a first angle (α) to the central axis (2); providing a first volume between the valve seat (3) and the needle orifice (6); and a first edge between the valve seat (3) and the first volume; wherein the first volume is chosen such that fuel flow remains substantially laminar as it passes over the first edge; providing an annulus (10) at the base of the first volume, radially outwardly of the needle orifice (6), wherein the annulus (10) is in a plane perpendicular to the central axis (2) and a second edge formed between the annulus (10) and the needle orifice (6); wherein fluid passing over the second edge is caused to cavitate, such that deposits in the needle orifice (6) are substantially removed.

2. A method according to claim 1, wherein a wall (8) of

the first volume is inclined at a second angle (β) to the central axis (2).

3. A method according to claim 1 or claim 2, wherein the first volume comprises a truncated cone.

4. A method according to any preceding claim, wherein the first angle (α) is 51°.

5. A method according to any one of claims 2 to 4, wherein the second angle (β) is 15°.

Patentansprüche

1. Verfahren zur Reduzierung von Ablagerungen in einem Kraftstoffinjektor (1), wobei das Verfahren umfasst: Vorsehen eines Kraftstoffdurchflusskanals um eine Mittelachse (2) des Kraftstoffinjektors (1) herum, wobei der Kanal einen Ventilsitz (3) und eine Nadelöffnung (6) aufweist; Einstellen des Ventilsitzes (3), so dass er unter einem ersten Winkel (α) zu der Mittelachse (2) geneigt ist; Vorsehen eines ersten Volumens zwischen dem Ventilsitz (3) und der Nadelöffnung (6); und eines ersten Randes zwischen dem Ventilsitz (3) und dem ersten Volumen; wobei das erste Volumen derart gewählt ist, dass der Kraftstofffluss im Wesentlichen laminar bleibt, wenn er den ersten Rand passiert; Vorsehen eines Ringes (10) am Boden des ersten Volumens, radial außerhalb der Nadelöffnung (6), wobei sich der Ring (10) in einer Ebene befindet, die zu der Mittelachse (2) senkrecht ist, und eines zweiten Randes, der zwischen dem Ring (10) und der Nadelöffnung (6) ausgebildet ist; wobei Fluid, das über den zweite Rand strömt, zum Kavitieren gebracht wird, derart, dass Ablagerungen in der Nadelöffnung (6) im Wesentlichen entfernt werden.

2. Verfahren nach Anspruch 1, wobei eine Wand (8) des ersten Volumens unter einem zweiten Winkel (β) zu der Mittelachse (2) geneigt ist.

3. Verfahren nach Anspruch 1 oder Anspruch 2, wobei das erste Volumen einen Kegelstumpf umfasst.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei der erste Winkel (α) 51° beträgt.

5. Verfahren nach einem der Ansprüche 2 bis 4, wobei der zweite Winkel (β) 15° beträgt.

Revendications

1. Procédé de minimisation de dépôts dans un injecteur (1) de carburant, procédé dans lequel on prévoit un passage pour un courant de carburant autour d'un axe (2) central de l'injecteur (1) de carburant, le passage comprenant un siège (3) de soupape et un orifice (6) de pointeau ; on met le siège (3) de soupape de manière à ce qu'il soit incliné d'un premier angle (α) par rapport à l'axe (2) central ; on prévoit un premier volume entre le siège (3) de soupape et l'orifice (6) de pointeau ; dans lequel on choisit le premier volume, de manière à ce que le courant de carburant reste sensiblement laminaire, alors qu'il passe sur le premier bord ; on prévoit un espace (10) annulaire à la base du premier volume, radialement vers l'extérieur de l'orifice (6) de pointeau, l'espace (10) annulaire étant dans un plan perpendiculaire à l'axe (2) central et un second bord étant formé entre l'espace (10) annulaire et l'orifice (6) de pointeau ; dans lequel du fluide passant sur le second bord est mis en cavitation, de sorte que des dépôts dans l'orifice (6) de pointeau sont sensiblement éliminés.

2. Procédé suivant la revendication 1, dans lequel une paroi (8) du premier volume est inclinée d'un deuxième angle (β) par rapport à l'axe (2) central.

3. Procédé suivant la revendication 1 ou la revendication 2, dans lequel le premier volume comprend un cône tronqué.

4. Procédé suivant l'une quelconque des revendications précédentes, dans lequel le premier angle (α) est de 51°.

5. Procédé suivant l'une quelconque des revendications 2 à 4, dans lequel le deuxième angle (β) est de 15°.

FIG 1

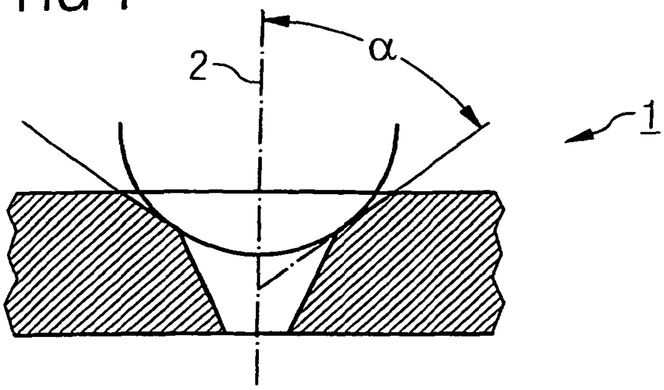


FIG 2

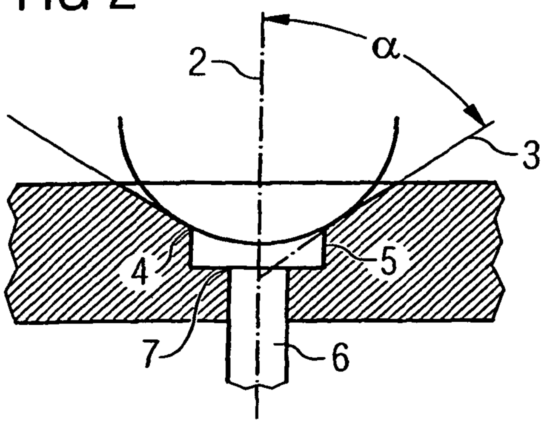


FIG 3

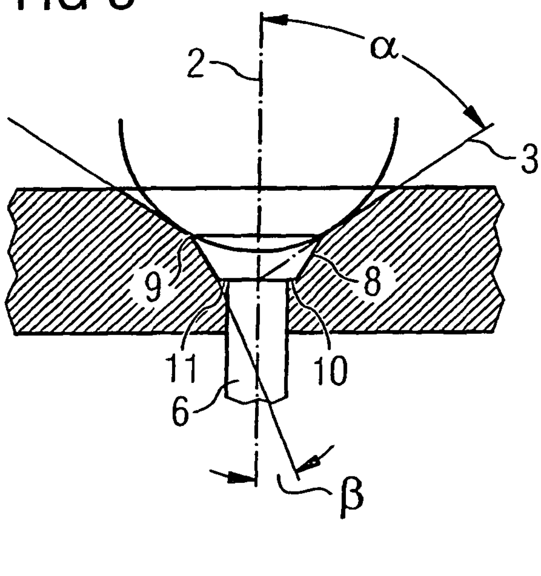
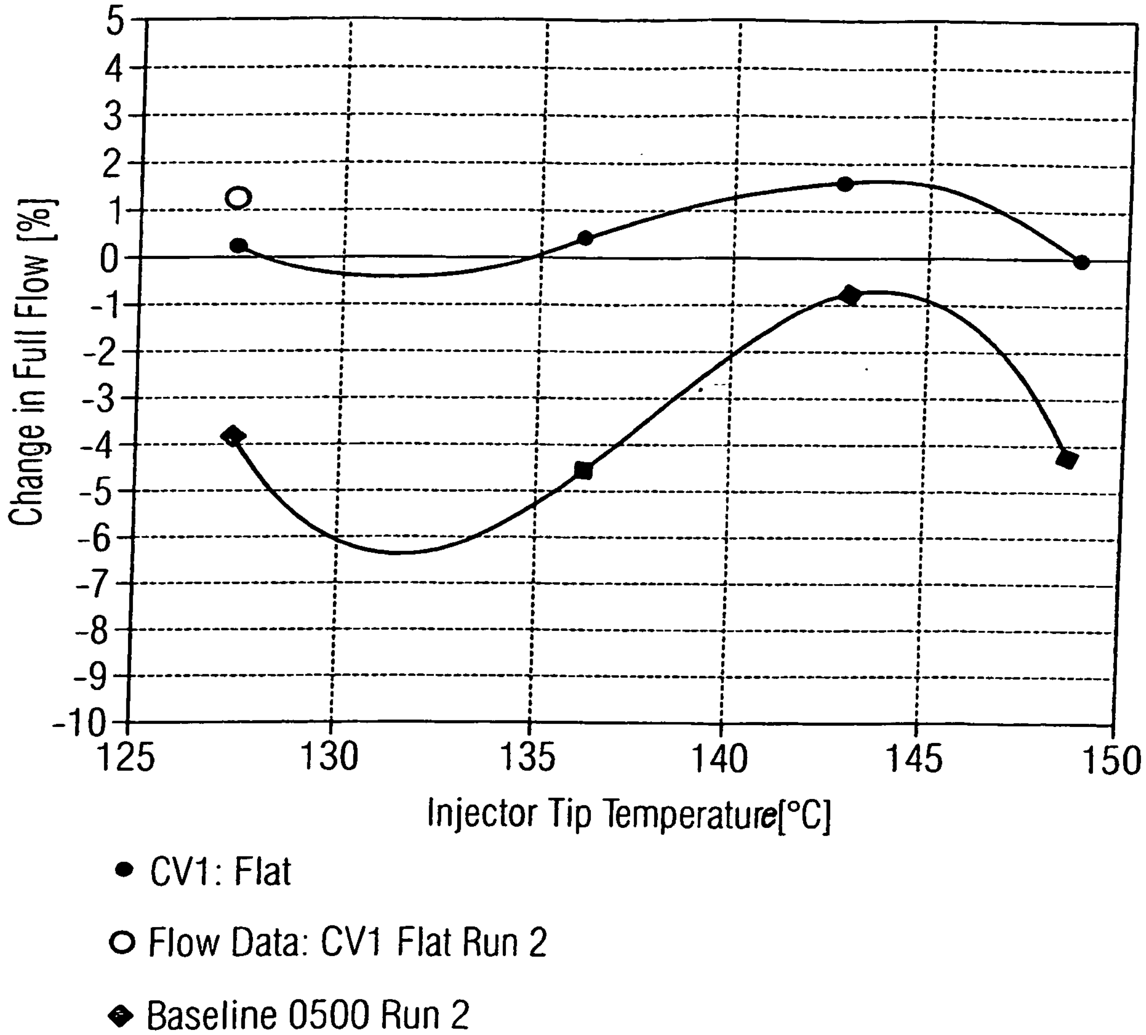


FIG 4


5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Change in Full Flow [%]
125
130
135
140
145
150
Injector Tip Temperature[°C]
CV1: Flat
Flow Data: CV1 Flat Run 2
Baseline 0500 Run 2

REFERENCES CITED IN THE DESCRIPTION

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