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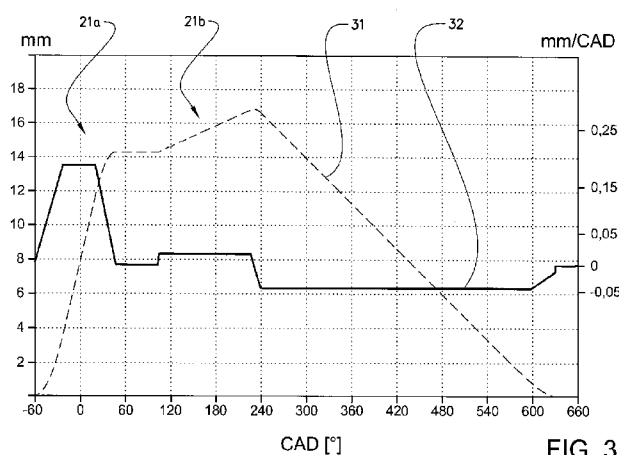


FIG. 3

(57) Abstract: The invention concerns a cam shaft device (1) configured to be rotationally arranged in association with an internal combustion engine (10) having at least one cylinder (11) and a fuel injector (5) arranged to inject fuel into said cylinder (11), said cam shaft device (1) comprising a cam member (21) configured to act upon the fuel injector (5) during rotation of the cam shaft device (1) such as to intermittently actuate the fuel injector (5), wherein the cam member (21) comprises a first portion (21a) intended to actuate the fuel injector (5) in a combustion stage of the cylinder (11) so as to inject fuel to be combusted in the cylinder (11) during operation of the engine (10). The invention is characterized in that the cam member (21) comprises a second portion (21b) configured to actuate the fuel injector (5) at a stage later than the combustion stage during rotation of the cam shaft device (1) so as to inject fuel that is not to be combusted but allowed to leave the cylinder (11) together with combustion products from the combustion stage. The invention also concerns an internal combustion engine (10) comprising such a device (1), and to a method for injecting fuel into a cylinder (11) of such an engine (10).

Cam shaft device and engine comprising such a device**TECHNICAL FIELD**

This invention relates to a cam shaft device for actuating a fuel injector that
5 injects fuel into a cylinder of an internal combustion engine, to an internal
combustion engine comprising such a device, and to a method for injecting
fuel into a cylinder of such an engine. In particular, the invention relates to
injection of fuel to be combusted in an exhaust gas system for regeneration
purposes.

10

BACKGROUND OF THE INVENTION

Regeneration of an exhaust gas after-treatment unit of a vehicle, such as a
particulate filter arranged in the exhaust gas system of a truck, typically
involves increasing the temperature in the exhaust gas system by supplying
15 fuel to the exhaust gas. Oxidation/combustion of this fuel in the exhaust gas
system generates the increased temperature.

The fuel may be supplied/injected directly into the exhaust gas, for instance
by the use of a fuel injector arranged downstream of the internal combustion
20 engine. This is sometimes referred to as an AHI (After-treatment
Hydrocarbon Injector).

As an alternative to a separate AHI system it has been proposed to use the
fuel injection system arranged at the engine to supply fuel to the exhaust gas
25 system. By injecting fuel very late in the engine cycle ("late post injection")
this fuel will not combust in the cylinders but instead be pushed out into the
exhaust system.

US2008/0135014 discloses an example on how to carry out such late post
30 injection. This solution relates, however, only to engines equipped with a
common rail system for injecting fuel where e.g. the injection needle can be
controlled by piezo-electronic means.

There is still a need for improvements related to the problem of increasing the temperature in the exhaust gas system for regeneration purposes, in particular for internal combustion engines that are not equipped with a common rail system but with separate unit injectors.

SUMMARY OF THE INVENTION

The invention concerns a cam shaft device configured to be rotationally arranged in association with an internal combustion engine having at least one cylinder and a fuel injector arranged to inject fuel into said cylinder, said cam shaft device comprising a cam member configured to act upon the fuel injector during rotation of the cam shaft device such as to intermittently actuate the fuel injector, wherein the cam member comprises a first portion intended to actuate the fuel injector in a combustion stage of the cylinder so as to inject fuel to be combusted in the cylinder during operation of the engine.

The first portion of the cam member is thus intended to carry out the function of providing the fuel to be combusted for the power stroke (expansion stroke) of the engine. In the power stroke a piston is forced to move through the cylinder from its TDC position towards the opposite end of the cylinder while at the same time rotating a crankshaft connected to the piston. The combustion stage, i.e. the actual combustion of the fuel, is performed when the piston is close to its TDC position, generally in the beginning of the power stroke. Where the engine is provided with unit injectors (one per cylinder) actuated by a cam member, a non-circular and/or eccentric cam member normally acts upon the fuel injector once per camshaft revolution, and in a four-stroke engine two full rotations of the crankshaft occur for each rotation of the camshaft. The shape of the cam member transforms the rotational motion of the camshaft to a linear motion that is used to increase the fuel pressure inside the injector, e.g. by pressing onto a plunger that in turn presses onto a fuel volume contained in a channel system in the injector. The

cam member does not necessarily have to press directly onto the plunger of the injector but onto e.g. a rocker arm that presses onto the plunger. By generating a fuel pressure that is higher than a certain minimum level defined by e.g. a needle spring, the needle (or other type of valve) opens and allows
5 the pressurized fuel to be injected into the cylinder.

In the inventive cam shaft device the cam member is provided with a second portion that actuates the fuel injector at a stage later than the combustion stage during rotation of the cam shaft device so as to inject fuel that is not to
10 be combusted but allowed to leave the cylinder together with combustion products from the combustion stage. This means that the fuel is injected so late that it does not take part in the combustion process but so early that the injected fuel will follow the exhaust gases from the combustion out from the cylinder during an exhaust stroke of the engine where the piston forces the
15 gases out (before the next stroke where air is introduced into the cylinder to be used in the next combustion stage).

This late fuel injection is thus carried out sometime during the period starting just after the combustion where the piston moves through the cylinder from
20 its TDC position towards the opposite end of the cylinder (the bottom dead center, BDC, position) and ending just before the piston again reaches its TDC position (in a four-stroke engine). Expressed in crank angle degrees (CAD), this period for late fuel injection extends between about 50 to 300° (CAD) (where, for a four-stroke engine, 0° corresponds to the TDC position of
25 the piston at the beginning of the power stroke, 180° corresponds to the BDC position of the piston at the beginning of the exhaust stroke, 360° corresponds to the TDC position of the piston at the beginning of the air intake stroke, 540° corresponds to the BDC position of the piston at the beginning of the compression stroke, and 720° corresponds to 0°, i.e. to two
30 full revolutions of the crankshaft and to one full revolution of the camshaft). Tests have shown that a preferable period for conducting such late fuel injection is around 100-270° (CAD).

An advantageous effect of the present invention is that a conventional fuel injector already installed at the cylinder of the engine can be used to inject fuel into the exhaust gases for later combustion in the exhaust gas system for the purpose of regenerating exhaust gas after-treatment units. Thereby the additional cost and work associated with the use of an additional injector placed in the exhaust gas system can be avoided. As described more in detail below, this also enables, for common injector types, the generation of one or several small, low-pressure injection pulses which reduces the risk of spraying fuel onto the walls of the cylinder which may lead to interaction with lubricating oil and reduce engine durability. Moreover, the inventive way of producing late fuel injection is simpler than controlling a common rail system.

Fuel injectors are commonly electronically controlled which means that, even if the injector is hydraulically actuated by the mechanically actuating cam member, the late fuel injection can be electronically inactivated during normal operation of the engine and activated only when regeneration of the exhaust gas system is desired.

The cam member extends only over a portion of the length of the cam shaft device. A plurality of cam members are typically arranged along the cam shaft device, where some of the cam members are intended to actuate injectors of other cylinders and some are intended to actuate cylinder valves. One or several fuel injection cam members can be provided with the inventive second portion.

In an embodiment of the invention, the cam member comprises a circumferential surface intended to act upon the fuel injector during rotation of the cam shaft device, wherein a distance between the circumferential surface and an axis of rotation of the cam shaft device varies along the circumferential surface.

In an embodiment of the invention the distance between the circumferential surface and the axis of rotation of the cam shaft device increases, with reference to the intended direction of rotation of the cam shaft device, along at least a part of both the first and the second portion.

5

In an embodiment of the invention said distance increases with a rate that is significantly lower along the second portion than along the first portion.

Thus, the second portion has a significantly lower cam rate than the first portion which is adapted to inject fuel efficiently for the combustion stage. This means that, when the cam shaft device rotates and the cam member acts in a linear direction upon the fuel injector, the linear action is significantly slower when the second portion of the cam member acts onto the injector than when the first portion acts onto the injector. By using an electronic unit injector in combination with the low cam rate of the second portion, at least after adaptation of the lower cam rate to the particular injector used, it is possible to achieve an advantageous injection profile for the late post injection of fuel:

When the second portion acts upon the injector it will cause the injector to open and inject fuel to the combustion chamber, but the low cam rate of the second portion will result in a relatively slow movement of a plunger and a relatively slow pressure increase in the injector. The injection of the fuel creates a pressure drop in the injector that makes the injection needle to close again since the fuel pressure increase is not sufficiently fast to keep the injector needle open (in contrast to when the first portion acts onto the injector where the pressure increases much faster). When the needle is closed the injection is stopped. As the second portion of the cam member still presses onto and moves the plunger, the fuel pressure in the injector increases causing the needle to open again. This process will then be repeated until the second portion no longer generates a pressure in the injector. During this late post injection period the plunger motion is thus too

slow to constantly keep the internal fuel pressure above the needle spring limit above which the needle valve opens and allows injection. In this way a series of fuel pulses can be created during the time period where the second portion of the cam member acts onto the injector. These pulses will have a
5 high frequency and each pulse will have a smaller volume and a lower velocity than conventional fuel pulses which prevents the fuel of these small pulses from hitting the cylinder walls. Avoiding spraying fuel onto the cylinder walls after the combustion process is an advantage as it may affect the lubrication and the durability of the engine. An effect of the low cam rate of
10 the second portion is thus that it becomes possible to generate a plurality of late small-volume low-velocity fuel injections.

Depending on the structure of the injector, for instance if it is designed to close the outlet at an internal fuel pressure that is lower than required for
15 opening the outlet, the low cam rate of the second portion can be used to create a pulse that is longer in time and where the fuel pressure and velocity is relatively low. In such a case it is not needed to create a series of small pulses to avoid the fuel from hitting the cylinder walls.

20 The exact magnitude of the cam rates of the first and second portion depends e.g. on what type of engine (size/power, intended rpm, etc.) and fuel injector (plunge diameter, nozzle flow, needle lift design, etc.) that are used in the particular application. As an example for a four-stroke heavy-duty diesel engine with six cylinders, the cam rate for the second portion can be 0.02
25 mm/degree (CAD) (i.e. 0.04 mm/degree cam shaft degree), extending between 110-260° (CAD), and for the first portion 0.2 mm/degree (CAD) (i.e. 0.4 mm/degree cam shaft degree), extending between 680-720° (or -40 to 0°) (CAD).

30 In an embodiment of the invention the increase rate of the second portion is in the interval 3-50%, preferably 5-20% of the increase rate of the first portion.

The invention also concerns an internal combustion engine, comprising

- at least one cylinder

- a fuel injector arranged to inject fuel into said cylinder

5 - a rotationally arranged cam shaft device comprising a cam member configured to act upon the fuel injector during rotation of the cam shaft device such as to intermittently actuate the fuel injector,

wherein the cam member comprises a first portion intended to actuate the fuel injector in a combustion stage of the cylinder so as to inject fuel to be

10 combusted in the cylinder during operation of the engine.

In the inventive engine the cam member comprises a second portion configured to actuate the fuel injector at a stage later than the combustion stage during rotation of the cam shaft device so as to inject fuel that is not to

15 be combusted but allowed to leave the cylinder together with combustion products from the combustion stage.

In an embodiment the engine comprises a piston arranged to move between two end positions in the cylinder during operation of the engine, wherein the

20 piston is connected to a crank shaft device in such a way that the piston returns to the same position after a revolution of 360° crank angle degrees (CAD), wherein the combustion stage is performed when the piston is close

to a first end position at 0° (CAD), and wherein the second portion of the cam member has an extension such that the injector actuation later than the

25 combustion stage is performed within the interval of 50-300° (CAD), preferably within the interval of 100-270° (CAD), during operation of the engine. The injector actuation later than the combustion stage can be

performed over a part only of these intervals.

30 In an embodiment the fuel injector comprises

- a movably arranged plunger member upon which the cam member is arranged to act,

- an internal fuel channel connected to the plunger member such that a fuel pressure in the channel can be varied by moving the plunger member,
 - an outlet through which fuel is discharged when injected into the cylinder, and
- 5 - an outlet valve member capable of preventing discharge through the outlet when the fuel pressure in the fuel channel is below a threshold value.

By slowly increasing the fuel pressure in an injector of the above type, i.e. slowly compared to the rapid pressure increase before injecting fuel for the combustion process, it is possible to generate a plurality of smaller fuel pulses as described above. Accordingly, by letting the second portion of the cam member slowly press onto the plunger member, directly or via e.g. a rocker arm, the plurality of smaller fuel pulses can be generated. The exact shape of the second portion of the cam member can be adapted to the particular engine and injector to be used. Conversely, the injector can be adapted or properly chosen to fit a particular cam member design.

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The injector may also comprise a spill valve capable of connecting and disconnecting the internal fuel channel with a supply of fuel outside of the injector. When activating the spill valve it closes the internal channel so that the fuel pressure inside the closed channel can increase when moving the plunger member.

20

In an embodiment the inventive engine the cam member comprises a circumferential surface intended to act upon the fuel injector during rotation of the cam shaft device, wherein a distance between the circumferential surface and an axis of rotation of the cam shaft device varies along the circumferential surface. Preferably, the distance between the circumferential surface and the axis of rotation of the cam shaft device increases, with reference to the intended direction of rotation of the cam shaft device, along at least a part of both the first and the second portion. Preferably, said

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distance increases with a rate that is significantly lower along the second portion than along the first portion.

5 The invention also concerns a method for injecting fuel into a cylinder of an internal combustion engine of the above type. The method comprises the step of rotating the cam shaft device so that the second portion of the cam member actuates the fuel injector at a stage later than the combustion stage so as to inject fuel that is not to be combusted but allowed to leave the cylinder together with combustion products from the combustion stage.

10

In an embodiment of the inventive method the engine comprises a fuel injector of the above type, wherein the second portion of the cam member acts upon the plunger member in a manner sufficiently slow to allow the outlet valve to open, to allow fuel discharge, to close, to prevent fuel
15 discharge, and to open again, to allow fuel discharge again, while the second portion of the cam member acts upon the plunger member.

In this embodiment the outlet valve thus opens at least two times such as to generate a plurality of (smaller) fuel injections as described above. The valve
20 may of course open and close more than two times during the time period when the second portion of the cam member acts upon the plunger member.

BRIEF DESCRIPTION OF DRAWINGS

In the description of the invention given below reference is made to the
25 following figures, in which:

- Figure 1 shows a schematic sectional view of a part of an internal combustion engine according to an embodiment of the invention,
Figure 2 shows a side view of the outer perimeter of an embodiment of a cam member according to the invention in comparison with a
30 conventional cam member and a circle,
Figure 3 shows the lift and lift rate as a function of crank angle degree for the cam member of figure 2, and

Figure 4 shows in a schematic view the function of a fuel injector when actuated by an inventive cam member.

DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

5 Figure 1 shows a part of an internal combustion engine 10 comprising a cylinder 11, a fuel injector 5 arranged to inject fuel into said cylinder 11, a rotationally arranged cam shaft device 1 comprising a cam member 21 configured to act, via rocker arm 2, upon a plunger member 3 of the fuel
10 injector 5 during rotation of the cam shaft device 1 such as to intermittently actuate the fuel injector 5.

The cam shaft device 1 extends in a direction perpendicular to the two-dimensional figure 1 and is in a conventional way provided with a plurality of cam members (not shown) and rocker arms (not shown) for actuating valves
15 (not shown) and further fuel injectors (not shown) at other cylinders (not shown) of the engine 1. Only the cam member 21 is shown in figure 1 (in a sectional view).

The engine 10 further comprises a piston 12 arranged to move between two
20 end positions, top dead center (TDC) and bottom dead center (BDC), in the cylinder 11 during operation of the engine. The piston 12 is connected in a conventional way to a crank shaft (not shown) in such a way that the piston returns to the same position after a revolution of 360° crank angle degrees (CAD). The engine 10 is a four-stroke engine where, conventionally, two full
25 rotations of the crankshaft occur for each rotation of the camshaft 1, rotationally synchronized by means of e.g. a cam belt.

The fuel injector 5 comprises the movably arranged plunger member 3 upon which the cam member 21 is arranged to act (via the rocker arm 2), an
30 internal fuel channel or volume 6 connected to the plunger member 3 such that a fuel pressure in the channel 6 can be varied by moving the plunger member 3, an outlet nozzle 9 through which fuel is discharged when injected

into the cylinder 11, an outlet valve member in the form of a spring-biased needle 8 capable of preventing discharge through the outlet 9 when the fuel pressure in the fuel channel 6 is below a threshold value (defined by the spring). The fuel injector 5 is electronically controlled and hydraulically actuated (by the pressurized fuel). The injector 5 further comprises a spill valve (not shown) for allowing supply of fuel to the channel 6 and for closing the internal channel 6 so that the fuel pressure can increase therein and force the needle 8 to open when the pressure is sufficient. The structure and function of the fuel injector 5 is well known as such.

10

Figure 2 shows a side view of the outer perimeter of the cam member 21. The cam member 21 has a first portion 21a and a second portion 21b which are further described below. The corresponding crank angle degree (CAD) is indicated on the axes (during one rotation of the cam shaft/cam member the crank shaft makes two rotations), i.e. this is the corresponding CAD when the cam member 21 is arranged in an engine as exemplified in figure 1. As a comparison, figure 2 also shows the perimeter of a corresponding conventional cam member 22. A circle 23 is also shown in figure 2, having its center point positioned at the center point of a rotational axis of the cam members 21 and 22 (and of the cam shaft device 1).

20

The outer perimeter of the cam member 21 indicates the position and shape of a circumferential surface of the cam member 21, which surface is intended to act via the rocker arm 2 upon (the plunger member 3 of) the fuel injector 5 during rotation of the cam shaft device 1. As can be seen in figure 2, a distance between the circumferential surface, i.e. the outer perimeter, and the axis of rotation varies along the circumferential surface. The term "lift" is used to quantify this distance in relation to the circle 23.

25

At around 630 CAD this distance is at a minimum, i.e. the lift is zero. The distance increases (with reference to the intended direction of rotation of the cam shaft device 1) along a first portion 21a in the approximate range -60 to

30

50 CAD (=660 to 50 CAD) and along a second portion 21b in the approximate range 110 to 230 CAD (see also figure 3). That this distance increases means that, when the cam shaft device 1 with its cam member 21 is arranged as e.g. in figure 1, the plunger member 3 is moved such as to
5 increase the fuel pressure in the channel 6 in the injector 5. As will be described further below, the magnitude of the rate of the increase of this distance is important, i.e. it is important how much this distance increases per CAD. In the embodiment shown here, the distance between the circumferential surface of the cam member 21 and the axis of rotation of the
10 cam shaft device 1 (the lift) increases with a rate that is significantly lower along the second portion 21b than along the first portion 21a.

Figure 3 shows the lift 31 and lift rate 32 as a function of crank angle degree for the cam member of figure 2. The lift 31 in mm in relation to the circle 23 is
15 indicated on the left axis. The lift rate 32 in mm/CAD is given on the right axis. The first and second portions 21a, 21b (see figure 2) are also indicated. Figure 3 shows that the first portion 21a extends from around -60 to 50 CAD with a lift rate of around 0.2 mm/CAD in the interval -20 to 20 CAD, and that the second portion 21b extends from around 110 to 230 CAD with a general
20 lift rate of around 0.02 mm/CAD, i.e. around 10% of the lift rate of the first portion 21a.

When the cam shaft device 1 is properly arranged in an engine it actuates directly or indirectly the fuel injector 5, i.e. it presses or pushes or similar
25 directly or indirectly onto the fuel injector 5, so that the fuel pressure in the channel 6 increases. When the pressure exceeds the threshold value of the outlet valve/needle spring 8, fuel is discharged/injected into the cylinder 11.

The first portion 21a of the cam member 21 is intended to actuate the fuel
30 injector 5 in a combustion stage of the cylinder 11 so as to inject fuel to be combusted in the cylinder 11 during operation of the engine. This is performed in a conventional way around 0 (720) CAD as mentioned above.

The lift rate along the first portion 21a (see figure 3) is sufficiently high to generate one large injected fuel pulse. The outlet valve 8 opens when the threshold pressure (the needle opening pressure) is reached and then stays open until the fuel to be injected has left the injector 5. The high lift rate (i.e. the fast movement of the plunge member 3) does not allow the fuel pressure to drop below the threshold value until the injection is completed. The fuel injected at this stage is (intended to be) entirely combusted in the cylinder 11 when the piston 12 is close to its TDC.

The second portion 21b of the cam member 21 is configured to actuate the fuel injector 5 at a stage later than the combustion stage during rotation of the cam shaft device 1 so as to inject fuel that is not to be combusted but allowed to leave the cylinder together with combustion products from the combustion stage. In the example shown here this is performed between around 110-230 CAD as mentioned above. The lift rate 32 along the second portion 21b, around 0.02 mm/CAD, is much lower than along the first portion 21a, around 0.2 mm/CAD (see figure 3). The lift rate 32 along the second portion 21b is sufficiently low (i.e. the movement of the plunger member 3 is sufficiently slow) to allow the fuel pressure to drop below the threshold value (below the needle closing pressure) so that the output valve/needle 8 closes.

As the cam shaft device 1 rotates further the second portion 21b forces the plunger member 3 to move further resulting in a (relatively slow) increase of the fuel pressure in the channel 6 until the needle 8 again opens and allows fuel to be injected in a second pulse into the cylinder 11. More than two pulses can be generated during the time interval when the second portion 21b acts onto the injector 5. These pulses of fuel are smaller in volume and the injected fuel has a lower velocity compared to the large pulse generated by the first portion 21a for/during the combustion stage.

30

Figure 4 shows in a schematic view an example of the function of a fuel injector of the type shown in figure 1 when actuated by the second portion

21b of the inventive cam member 21. Lines 41-44 show variations in plunger member 3 displacement 41, spill valve displacement 42, fuel pressure (injection pressure) 43 in channel 6, and fuel injection rate 44 as a function of time.

5

At $t = 2$ ms the plunger member 3 starts to move (line 41), the spill valve is activated so as to close the channel 6 and entrap the fuel (line 42) and the fuel pressure in the channel 6 increases (line 43). At $t = 4$ ms the threshold pressure value for the outlet valve 8 (i.e. the threshold value for the needle spring) is reached so that it opens and generates a first (small) injection of fuel (line 44) and a decrease in fuel pressure. At $t = 5$ ms the threshold pressure value for the outlet valve 8 is reached again so that it opens and generates a second (small) injection of fuel (line 44). This pattern is repeated at $t = 6$ ms leading to a third (small) fuel pulse. At $t = 6.5$ ms the movement of the plunger member 3 stops (line 41). At $t = 7$ ms the spill valve is inactivated (line 42).

In a later stage, i.e. some milliseconds later, the plunger member 3 is returned to its original position, typically by means of a helical spring arranged at the plunger member 3 so as to be compressed by the plunger member 3 during its movement towards the outlet nozzle 9.

This process can be repeated a number of times, i.e. over a number of cam shaft revolutions, until a sufficient amount of fuel has been transported into the exhaust gas system. To avoid injecting fuel at this late stage the spill valve can be set in a non-activated mode when the second portion 21b actuates the injector to prevent the fuel pressure inside the channel 6 to build up sufficiently for opening the outlet valve 8. (The spill valve can still be set in an activated mode when the first portion 21a actuates the injector to still allow the first portion 21a to induce fuel injection to continue normal power operation of the particular cylinder).

The invention is not limited by the embodiments described above but can be modified in various ways within the scope of the claims. For instance, it may be sufficient to produce one (small) late injection of fuel during one revolution of the crank shaft device 1, i.e. the line 44 in figure 4 may contain only one
5 peak.

Further, the outlet valve 8 and the spill valve can be arranged in different ways.

CLAIMS

1. Cam shaft device (1) configured to be rotationally arranged in association
5 with an internal combustion engine (10) having at least one cylinder (11) and
a fuel injector (5) arranged to inject fuel into said cylinder (11),
said cam shaft device (1) comprising a cam member (21) configured to act
upon the fuel injector (5) during rotation of the cam shaft device (1) such as
to intermittently actuate the fuel injector (5),
10 wherein the cam member (21) comprises a first portion (21a) intended to
actuate the fuel injector (5) in a combustion stage of the cylinder (11) so as to
inject fuel to be combusted in the cylinder (11) during operation of the engine
(10),
c h a r a c t e r i z e d i n
15 that the cam member (21) comprises a second portion (21b) configured to
actuate the fuel injector (5) at a stage later than the combustion stage during
rotation of the cam shaft device (1) so as to inject fuel that is not to be
combusted but allowed to leave the cylinder (11) together with combustion
products from the combustion stage.
20
2. Cam shaft device (1) according to claim 1,
c h a r a c t e r i z e d i n
that the cam member (21) comprises a circumferential surface intended to
act upon the fuel injector (5) during rotation of the cam shaft device (1),
25 wherein a distance between the circumferential surface and an axis of
rotation of the cam shaft device (1) varies along the circumferential surface.
3. Cam shaft device (1) according to claim 2,
c h a r a c t e r i z e d i n
30 that the distance between the circumferential surface and the axis of rotation
of the cam shaft device (1) increases, with reference to the intended direction

of rotation of the cam shaft device (1), along at least a part of both the first and the second portion (21a, 21b).

4. Cam shaft device (1) according to claim 3,

5 characterized in

that said distance increases with a rate that is significantly lower along the second portion (21b) than along the first portion (21a).

5. Cam shaft device (1) according to claim 4,

10 characterized in

that the increase rate of the second portion (21b) is in the interval 3-50%, preferably 5-20% of the increase rate of the first portion (21a).

6. Internal combustion engine (10), comprising

15 - at least one cylinder (11),

- a fuel injector (5) arranged to inject fuel into said cylinder (11),

- a rotationally arranged cam shaft device (1) comprising a cam member (21) configured to act upon the fuel injector (5) during rotation of the cam shaft device (1) such as to intermittently actuate the fuel injector (5),

20 wherein the cam member (21) comprises a first portion (21a) intended to actuate the fuel injector (5) in a combustion stage of the cylinder (11) so as to inject fuel to be combusted in the cylinder (11) during operation of the engine (10),

characterized in

25 that the cam member (21) comprises a second portion (21b) configured to actuate the fuel injector (5) at a stage later than the combustion stage during rotation of the cam shaft device (1) so as to inject fuel that is not to be combusted but allowed to leave the cylinder (11) together with combustion products from the combustion stage.

30

7. Internal combustion engine (10) according to claim 6,

wherein the engine (10) comprises a piston (12) arranged to move between two end positions in the cylinder (11) during operation of the engine (10), wherein the piston (10) is connected to a crank shaft device in such a way that the piston (10) returns to the same position after a revolution of 360° crank angle degrees (CAD),
5 wherein the combustion stage is performed when the piston (10) is close to a first end position at 0° (CAD), wherein the second portion (21b) of the cam member (21) has an extension such that the injector actuation later than the combustion stage is performed within the interval of 50-300° (CAD), preferably within the interval of 100-270° (CAD), during operation of the engine (10).
10

8. Internal combustion engine (10) according to claim 6 or 7, wherein the fuel injector (5) comprises
15 - a movably arranged plunger member (3) upon which the cam member (21) is arranged to act,
- an internal fuel channel (6) connected to the plunger member (3) such that a fuel pressure in the channel (6) can be varied by moving the plunger member (3),
20 - an outlet (9) through which fuel is discharged when injected into the cylinder (11),
- an outlet valve member (8) capable of preventing discharge through the outlet (9) when the fuel pressure in the fuel channel (6) is below a threshold value.

25
9. Internal combustion engine (10) according to any of claims 6-8, wherein the cam member (21) comprises a circumferential surface intended to act upon the fuel injector (5) during rotation of the cam shaft device (1), wherein a distance between the circumferential surface and an axis of rotation of the cam shaft device (1) varies along the circumferential surface.
30

10. Internal combustion engine (10) according to claim 9,

wherein the distance between the circumferential surface and the axis of rotation of the cam shaft device (1) increases, with reference to the intended direction of rotation of the cam shaft device (1), along at least a part of both the first and the second portion (21a, 21b).

5

11. Internal combustion engine (10) according to claim 10, wherein said distance increases with a rate that is significantly lower along the second portion (21b) than along the first portion (21a).

10 12. Internal combustion engine (10) according to claim 10 or 11, wherein the increase rate of the second portion (21b) is in the interval 3-50%, preferably 5-20% of the increase rate of the first portion (21a).

13. Method for injecting fuel into a cylinder (11) of an internal combustion
15 engine (10) according to any of claims 6-12, wherein the method comprises the step of
- rotating the cam shaft device (1) so that the second portion (21b) of the cam member (21) actuates the fuel injector (5) at a stage later than the combustion stage so as to inject fuel that is not to be combusted but allowed
20 to leave the cylinder (11) together with combustion products from the combustion stage.

14. Method according to claim 13, wherein the engine (10) comprises a fuel injector (5) according to claim 8, wherein the second portion (21b) of the cam
25 member (21) acts upon the plunger member (3) in a manner sufficiently slow to allow the outlet valve (8) to open, in order to allow fuel discharge, to close, in order to prevent fuel discharge, and to open again, in order to allow fuel discharge again, while the second portion (21b) of the cam member (21) acts upon the plunger member (3).

30

1/4

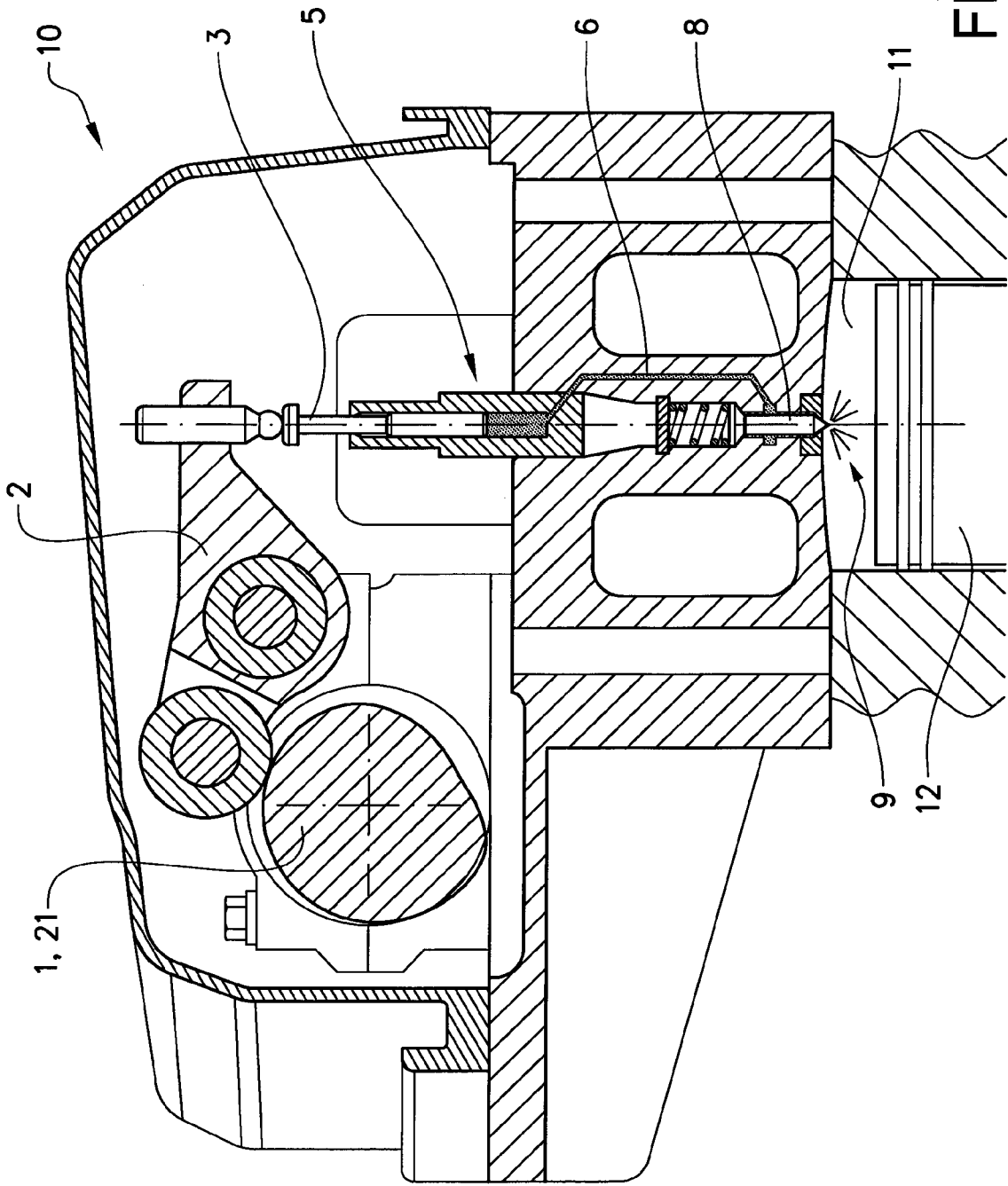


FIG. 1

2/4

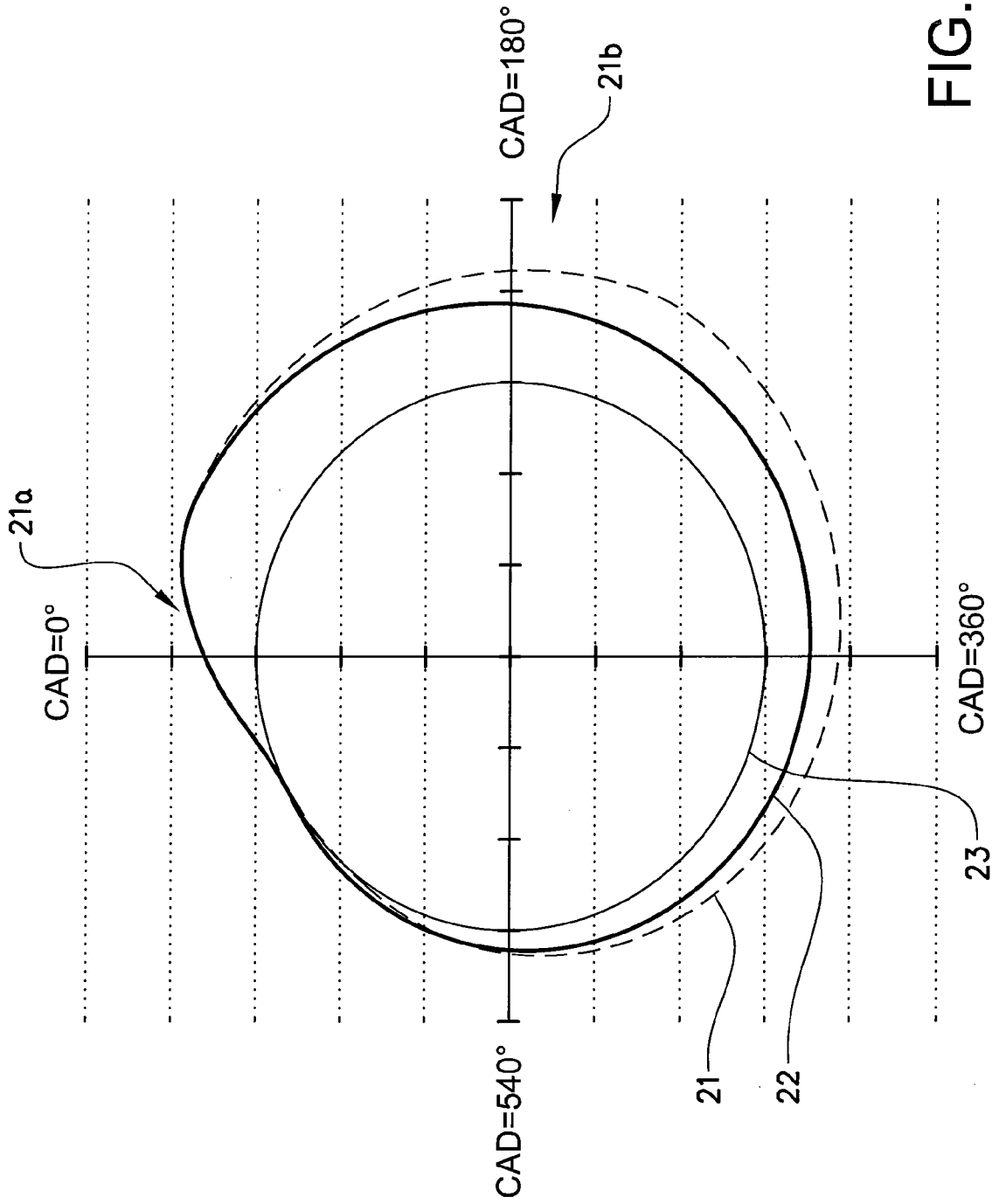


FIG. 2

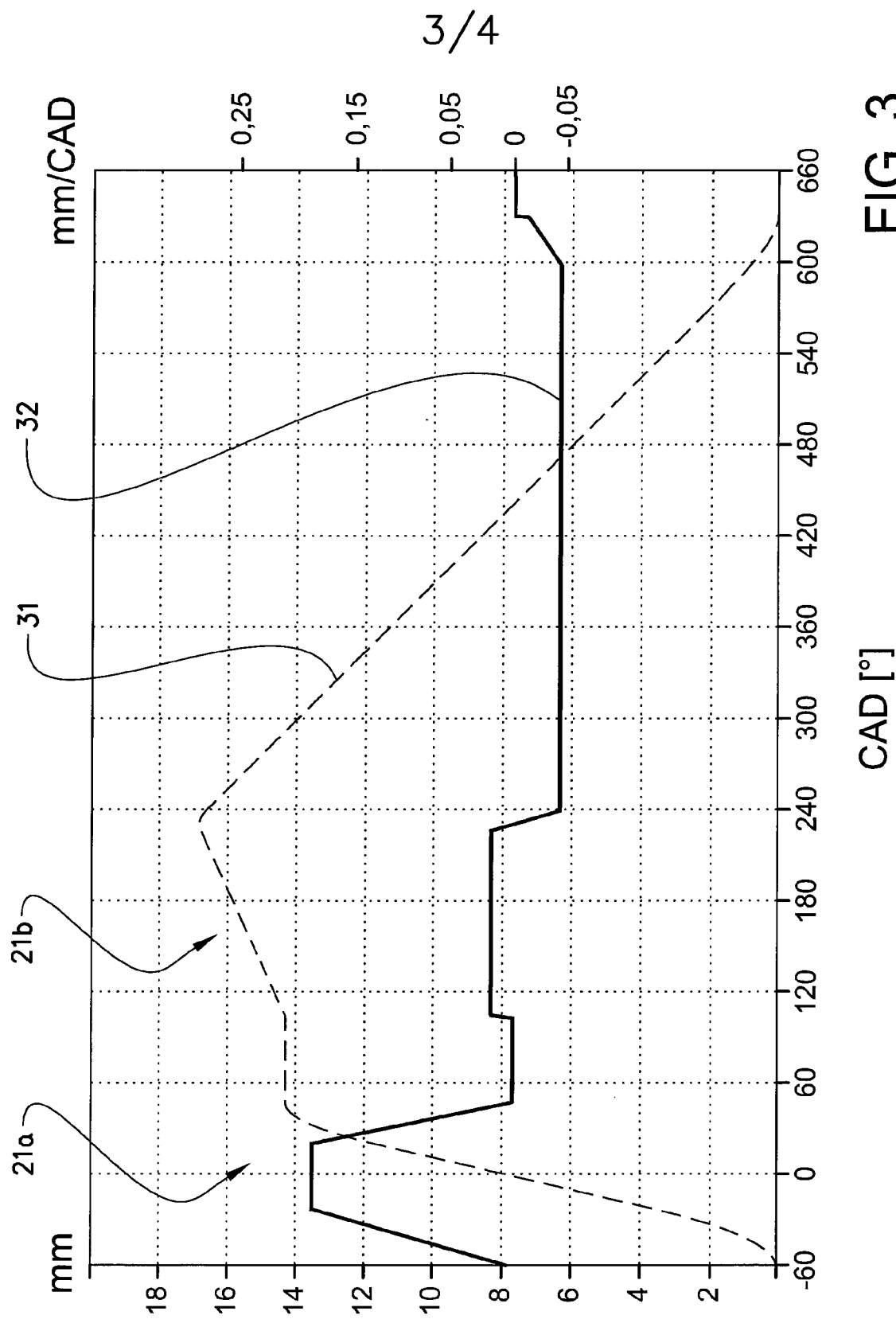


FIG. 3

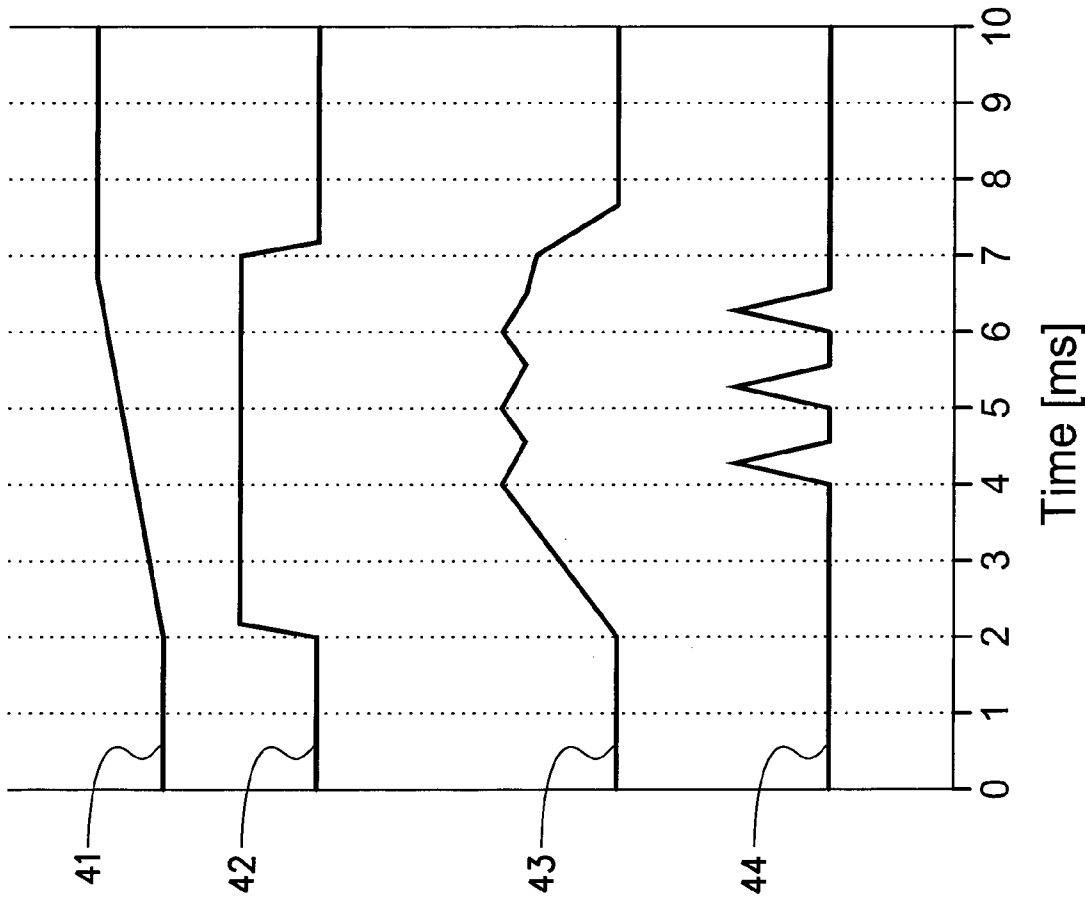


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/002984

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02M57/02 F02M45/02 F02D41/40 F02M61/14 F01N3/20
ADD. F01L1/053 F01L1/18

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02M F02D F01L F01N

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/070889 A1 (VOLVO LASTVAGNAR AB [SE]; PERSSON PER [SE]; WIMAN JAN [SE]; RICK JONAS) 12 September 2002 (2002-09-12) page 3, line 17 - page 4, line 27 page 6, lines 14-22; figures -----	1-14
X	WO 98/41753 A1 (VOLVO LASTVAGNAR AB [SE]; TENGROTH STELLAN [SE]; LEIRE LARSON BENGT [S]) 24 September 1998 (1998-09-24) figures -----	1-3, 6-10,13
A	FR 2 850 428 A1 (RENAULT SA [FR]) 30 July 2004 (2004-07-30) figures -----	1,2,6,8, 9



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

13 December 2013

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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