(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 4 553 313 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
14.05.2025 Bulletin 2025/20

(21) Application number: **23208103.4**

(22) Date of filing: **07.11.2023**

(51) International Patent Classification (IPC):
F02M 61/12 *(2006.01)* ***F02M 61/16*** *(2006.01)*
F02M 63/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F02M 61/12; F02M 61/16; F02M 63/0038;
F02M 2200/29; F02M 2200/50

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(71) Applicant: **VOLVO TRUCK CORPORATION**
405 08 Göteborg (SE)

(72) Inventor: **YUDANOV, Sergi**
426 69 Västra Frölunda (SE)

(74) Representative: **Zacco Sweden AB**
P.O. Box 5581
Löjtnantsgatan 21
114 85 Stockholm (SE)

(54) **A FUEL INJECTOR**

(57) A fuel injector comprises a needle movable within a nozzle body. The fuel injector has a closed state in which the needle is mated with a nozzle seat, and an open state in which the needle is spaced apart from the nozzle seat to allow fuel to be dispensed from the nozzle body. The needle and the nozzle body have mutually cooperating axial guide elements that guide the needle along a geometrical longitudinal axis of the needle. The guide elements present, with respect to said longitudinal axis, a rotational play between the needle and the nozzle body. A rotational stop is provided to limit the rotational play. The fuel injector further comprises a force transfer arrangement configured to provide to the needle a rotational force relative to said longitudinal axis, the rotational force biasing the needle to assume a fixed rotational position at said rotational stop relative to the nozzle body in said closed state of the fuel injector.

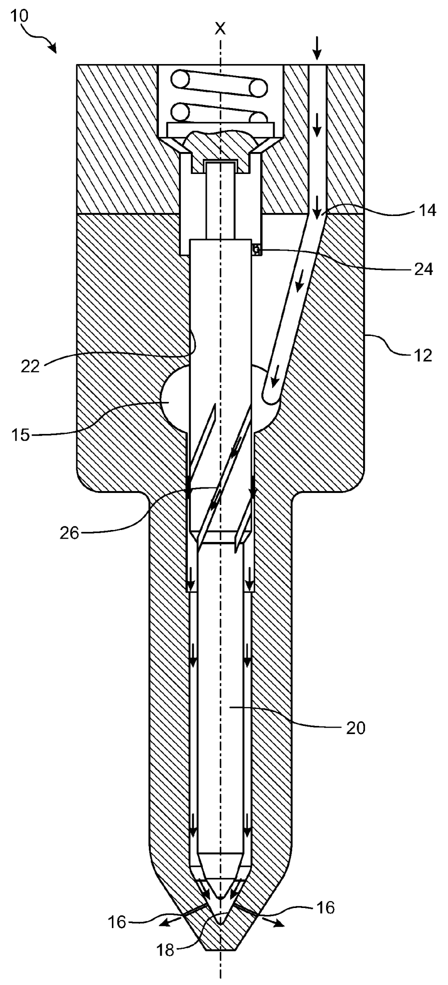

FIG. 2

EP 4 553 313 A1

Description

TECHNICAL FIELD

[0001] The disclosure relates generally to a fuel injector. In particular aspects, the disclosure relates to a fuel injector for an internal combustion engine system. The disclosure can be applied to heavy-duty vehicles, such as trucks, buses, and construction equipment, among other vehicle types. Although the disclosure may be described with respect to a particular vehicle, the disclosure is not restricted to any particular vehicle.

BACKGROUND

[0002] Fuel injectors for internal combustion engines normally include a needle that is movable within a nozzle body. The needle can be moved to contact a nozzle seat to close the fuel injector, and moved away from the nozzle seat to allow fuel to be injected into the internal combustion engine. Such known injectors may have a mechanical spline-like keying feature between the needle and the nozzle body which limits the range of rotation of the needle relative to the nozzle body. This promotes uneven wear of the contact surfaces such that, over time, a random pattern of convex and concave irregularities develops on one contact surface that tends to match a similar but opposing pattern of convex/concave irregularities on the opposite contact surface. The matching of those patterns promotes a fluid seal in the seat. However, the spline-like interface between the needle and the nozzle body is provided with a certain clearance to avoid undue friction that can disturb the accurately controlled axial movement of the needle relative to the nozzle body. This clearance allows a certain relative angular/rotational movement of the needle relative to the nozzle body. Such variation in relative angular/rotational position means that the formed irregularities in the contact surfaces will not always mate well enough to provide a tight seal, thereby presenting a risk of increased fuel leakage.

SUMMARY

[0003] According to a first aspect of the disclosure, there is provided a fuel injector, comprising:

- a nozzle body having an inlet for receiving fuel and an outlet for dispensing received fuel,
- a nozzle seat located within the nozzle body,
- a needle being movable within the nozzle body, selectively towards and away from the nozzle seat, wherein the fuel injector has:

    a closed state in which the needle is mated with the nozzle seat to prevent fuel from being dispensed from the nozzle body, and
    an open state in which the needle is spaced apart from the nozzle seat to allow fuel to be dispensed from the nozzle body,

  wherein the needle and the nozzle body have mutually cooperating axial guide elements that guide the needle along a geometrical longitudinal axis of the needle,
  wherein the guide elements present, with respect to said longitudinal axis, a rotational play between the needle and the nozzle body,
  wherein a rotational stop is provided to limit the rotational play,
  wherein the fuel injector further comprises:

    - a force transfer arrangement configured to provide to the needle a rotational force relative to said longitudinal axis, the rotational force biasing the needle to assume a fixed rotational position at said rotational stop relative to the nozzle body in said closed state of the fuel injector.

The first aspect of the disclosure may seek to avoid the problem of fuel leakage due to uncontrolled mating between the needle and the nozzle seat with respect to rotational direction of the needle. A technical benefit may include that by providing a way of rotationally biasing the needle and the nozzle body against each other with a controlled force, such that, when the needle mates with the nozzle seat, it tends to always end up in the same relative angular position, the angular position being defined by the rotational stop.

[0004] The rotational stop may be conceived in various manners. For example, in some examples the rotational stop may include a protrusion cooperating with a recess, such as a protrusion extending from one of said needle and said nozzle body and a cooperating (and slightly larger) recess provided in the other one of said needle and said nozzle body. In some examples, the rotational stop may include a void formed by a first recess in the needle facing a second recess in the nozzle body, wherein an element, such as a ball, may be provided in the void and dimensioned such that it extends into both recesses, thereby limiting the relative rotation between the needle and nozzle body. Yet another example for a rotational stop may be to provide a ratchet-configuration, which would limit rotation in one direction, wherein a torsional spring could be provided to limit rotation in the opposite direction.

[0005] Optionally in some examples, including in at least one preferred example, the force transfer arrangement forms part of the needle in the form of one or more angled peripheral surfaces of the needle, wherein kinetic energy of fuel flowing on said angled peripheral surfaces results in said rotational force being provided to the needle. A technical benefit may include that no separate force transfer arrangement needs to be provided, but instead the existing kinetic energy of the flowing fuel is made use of.

[0006] Optionally in some examples, including in at least one preferred example, the force transfer arrangement comprises one or more grooves provided on the surface of the needle, the one or more grooves being tilted relative to said longitudinal axis, wherein fuel flowing along the needle and on the tilted groove(s) provides for said rotational force. Analogously to the above discussion, a technical benefit may include that no separate force transfer arrangement needs to be provided for achieving the biasing of the needle.

[0007] Optionally in some examples, including in at least one preferred example, the force transfer arrangement comprises a separate component which subjects the needle to said rotational force. A technical benefit may include that a separate component can provide a force independently of any fuel flow being present or not around the needle. For example, if the needle has already reached the nozzle seat, but the rotational position is such that the irregularities in the contact surfaces of the needle and the nozzle seat are not matching, then there may be a small leakage, but the force of the fuel will be very low and may not be able to rotate the needle into its final matching position. By providing a separate component to provide the force, the biasing force can be applied to the needle even after it has come into contact with the nozzle seat.

[0008] Optionally in some examples, including in at least one preferred example, the force transfer arrangement comprises a resilient element which subjects the needle to said rotational force. Analogously with the above, a technical benefit may include that a resilient element may provide the biasing force to the needle even after it has come into contact with the nozzle seat.

[0009] Optionally in some examples, including in at least one preferred example, the resilient element is in the form of a torsion spring arranged between the nozzle body and the needle, wherein the torsion spring subjects the needle to said rotational force. A technical benefit may include that torsion springs are readily available and, analogously with the above discussion, provides the biasing force to the needle irrespective of the axial position of the needle.

[0010] Optionally in some examples, including in at least one preferred example, the mutually cooperating axial guide elements include one or more protrusions cooperating with respective recesses, wherein one of the nozzle body and the needle is provided with said one or more protrusions and the other one of the nozzle body and the needle is provided with said respective recesses. A technical benefit may include that such axial guide elements are simple to manufacture, yet provide efficient axial guiding. The protrusions and recesses may be in the form of splines, keys, grooves, etc. For axial guiding, suitably at least one of said protrusions and recesses may be elongate and extend in parallel with the central axis of the fuel injector. For example, a protrusion which has a relatively short axial extension, can be guided along a recess/groove having relatively long axial extension. Such a long recess may in some examples be provided in the needle, and in other examples be provided in the nozzle body. Conversely, in other examples, the protrusion may have a relatively long axial extension and the recess may have a relatively short axial extension. It should furthermore be understood, that in some examples, the protrusion as well as the recess may both be elongate in the axial extension, for example, of equal axial length. In other examples the mutually cooperating axial guide elements may include cylindrical guide surfaces cooperating with each other.

[0011] Optionally in some examples, including in at least one preferred example, the force transfer arrangement is configured to start rotating the needle before it reaches the nozzle seat. A technical benefit may include that, by allowing the needle to be rotated before having reached the seated state, various factors such as vibrations pushing away the needle at the last moment, may be avoided.

[0012] Optionally in some examples, including in at least one preferred example, the force transfer arrangement is configured to rotate the needle to said fixed rotational position when the needle has come into contact with the nozzle seat. A technical benefit may include that a correct position may be provided even if the correct rotational position has not yet been reached during the axial movement of the needle. It should thus be understood that the rotational biasing force may, in at least some examples, start already before the needle comes into contact with the nozzle seat, and then also continue after the needle has come into contact with the nozzle seat.

[0013] Optionally in some examples, including in at least one preferred example, said rotational stop is a single mechanical stop against continued rotation of the needle in one of a clockwise and counter-clockwise direction. A technical benefit may include that more play is allowed in the opposite direction, reducing the risk of frictional effects. In some examples, the rotation in the opposite direction may be limited by a spring force, such as from the previously discussed resilient element/torsion spring, and therefore in the opposite direction there would not be a limit at a particular fixed rotational position.

[0014] Optionally in some examples, including in at least one preferred example, said rotational stop is a first mechanical stop against continued rotation of the needle in one of a clockwise and counter-clockwise direction, wherein the fuel injection further comprises a second mechanical stop against continued rotation of the needle in the opposite one of said clockwise and counter-clockwise direction. A technical benefit may include that by having a limit in both rotational directions, the energy required to rotate the needle from one rotational end point to the other rotational end point may be conveniently controlled and anticipated.

[0015] Optionally in some examples, including in at least one preferred example, the fuel injector is normally in the closed state, and is configured to become opened by an electrical signal from an engine control module, ECM. A technical benefit may include that such control is efficient and provides short response time.

[0016] According to a second aspect of the disclosure, there is provided an internal combustion engine system comprising the fuel injector according to the first aspect, including any examples thereof, wherein the fuel injector is configured to, in the open state, inject fuel into a combustion chamber of the internal combustion engine system. The second aspect of the disclosure may seek to solve the corresponding problem and may include the corresponding benefits as the first aspect, including any examples thereof.

[0017] According to a third aspect of the disclosure, there is provided a vehicle comprising the fuel injector according to the first aspect, including any examples thereof, or internal combustion engine system according to the second aspect, including any examples thereof. The third aspect of the disclosure may seek to solve the corresponding problem and may include the corresponding benefits as the first aspect, including any examples thereof.

[0018] The disclosed aspects, examples (including any preferred examples), and/or accompanying claims may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art. Additional features and advantages are disclosed in the following description, claims, and drawings, and in part will be readily apparent therefrom to those skilled in the art or recognized by practicing the disclosure as described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Examples are described in more detail below with reference to the appended drawings.

- **FIG. 1** schematically illustrates a vehicle according to one example of this disclosure.
- **FIG. 2** schematically illustrates a fuel injector according to one example of this disclosure.
- **FIG. 3** schematically illustrates a fuel injector according to another example of this disclosure.
- **FIG. 4** schematically illustrates an example of a rotational stop which may be implemented in a fuel injector according to at least some examples of this disclosure.
- **FIG. 5** schematically illustrates another example of a rotational stop which may be implemented in a fuel injector according to at least some examples of this disclosure.
- **FIG. 6** schematically illustrates an internal combustion engine system according to one example of this disclosure.
- **FIG. 7** schematically illustrates a fuel injector according to a general example of this disclosure.

DETAILED DESCRIPTION

[0020] The detailed description set forth below provides information and examples of the disclosed technology with sufficient detail to enable those skilled in the art to practice the disclosure.

[0021] A fuel injector may be provided for supplying fuel into a cylinder of an internal combustion engine. The fuel injector may be inserted into an opening in a housing part to form a part of a fuel injection system. Such a fuel injector or fuel injection system may be used in an internal combustion engine, such as a diesel engine, wherein said engine can be used in any vehicle, such as a truck, bus, construction equipment, etc. A fuel injector may include a needle that is movable within a nozzle body. The needle can be moved to contact a nozzle seat to close the fuel injector, and moved away from the nozzle seat to allow fuel to be injected into the internal combustion engine. Known injectors may be subject to uneven wear of the contact surfaces between the needle and the nozzle seat such that, over time, a random pattern of convex and concave irregularities develops on one contact surface that tends to match a similar but opposing pattern of convex/concave irregularities on the opposite contact surface. The matching of those patterns promotes a fluid seal in the seat. However, the needle and the nozzle body are provided with a certain clearance which allows a certain relative angular/rotational movement of the needle relative to the nozzle body. Such variation in relative angular/rotational position means that the formed irregularities in the contact surfaces will not always mate well enough to provide a tight seal, thereby presenting a risk of increased fuel leakage. The present disclosure is based on the insight that a repeatable position is obtainable by combining a rotational stop with a force transfer arrangement, such that the needle may each time it is subjected to the rotational force provided by the force transfer arrangement always assume a fixed rotational position at the rotational stop in the closed state of the fuel injector. Thus, by forcing the needle to arrive to a predetermined position in the closed state of the fuel injector, uncertainty and variability of relative rotational orientation between contact surfaces may efficiently be avoided.

[0022] **FIG. 1** schematically illustrates a vehicle **1** according to one example of this disclosure. The exemplary illustration in **FIG. 1** shows a tractor unit for towing a trailer unit (not shown), which together make up a semitrailer vehicle. However, the teachings of this disclosure are applicable to other types of vehicles as well. For instance, the vehicle may be a different type of vehicle for cargo transport, such as a truck, or a truck with a dolly unit arranged to tow a trailer unit, etc. Other conceivable examples include a bus, construction equipment or other vehicle types. The vehicle **1** may be powered by an internal combustion engine (ICE). The illustrated vehicle **1** comprises a cabin **2** in which a driver may operate the vehicle **1.** However, in other exemplary embodiments the vehicle **1** may be an autonomous, i.e., self-driving, vehicle.

[0023] The vehicle **1** may comprise a fuel injector of this disclosure, some examples of which will be discussed below. In particular, the vehicle **1** may comprise an internal combustion engine system which in turn comprises a fuel injector of this disclosure. Such a fuel injector may be configured to, in the open state, inject fuel into a combustion chamber of the internal combustion engine system.

[0024] **FIG. 2** schematically illustrates a fuel injector **10** according to one example of this disclosure. The fuel injector **10** comprises a nozzle body **12** having an inlet **14** for receiving fuel (indicated by arrows). The inlet **14** may be connected to a nozzle chamber **15** for receiving fuel to be injected. The nozzle body **12** further has outlets **16** for dispensing received fuel. A nozzle seat **18** is located within the nozzle body **12.** The fuel injector **10** further comprises a needle **20** which may be reciprocally movable within the nozzle body **12.** In particular, the needle **20** may be selectively movable towards and away from the nozzle seat **18.** The fuel injector **10** has a closed state in which the needle **20** is mated with the nozzle seat **18** to prevent fuel from being dispensed from the nozzle body **12,** and an open state in which the needle **20** is spaced apart from the nozzle seat **18** to allow fuel to be dispensed from the nozzle body **12.** In **FIG. 2,** the open state of the fuel injector **10** is shown. Thus, the needle **20** has not reached its most axially advanced position. To change to a closed state of the fuel injector **10,** the needle **20** would be moved to an axially advanced position compared to that shown in **FIG. 2.** The needle **20** may thus be movable between an advanced/closed position and a retracted/open position. A purpose of the nozzle seat **18** is to hydraulically separate the nozzle chamber **15** from the outlets **16** in the closed position of the needle **20,** i.e., in the closed state of the fuel injector **10.** The needle **20** and the nozzle body **12** may suitably be concentrically arranged relative to each other and may have a controlled clearance in a guide **22** between each other. The guide **22** may be formed by mutually cooperating axial guide elements of the needle **20** and nozzle body **12,** respectively, which guide elements guide the needle **20** along a geometrical longitudinal axis **X** of the needle **20.** The guide elements present, with respect to said longitudinal axis **X,** a rotational play between the needle **20** and the nozzle body **12.** As illustrated in **FIG. 2,** the guide elements may, in some examples be formed by cooperating cylindrical surfaces of the needle **20** and nozzle body **22.** In other examples, the guide elements may include cooperating protrusions and recesses.

[0025] **FIG. 2** also illustrates schematically that the fuel injector **10** further comprises a rotational stop **24.** The rotational stop **24** is provided to limit the rotational play between the needle **20** and the nozzle body **12.**

[0026] The fuel injector **10** further comprises a force transfer arrangement **26** configured to provide to the needle **20** a rotational force relative to said longitudinal axis ***X.*** The purpose of the rotational force is to bias the needle **20** into assuming, at said rotational stop **24,** a fixed rotational position relative to the nozzle body **12** in the closed state of the fuel injector **10.** Thus, the needle **20** may be rotated to a predetermined rotational orientation, defined by the rotational stop **24,** each time the needle **20** forms contact with the nozzle seat **18** in the closed state of the fuel injector **10.**

[0027] In the illustrated example in **FIG. 2,** the force transfer arrangement **26** may form part of the needle **20** in the form of one or more angled peripheral surfaces of the needle **20.** The kinetic energy of fuel flowing (indicated by the arrows) on said angled peripheral surfaces results in said rotational force being provided to the needle **20.** Thus, when the needle **20** is in a lifted position and fuel is being injected, as the fluid passes along the angled peripheral surfaces, the needle **20** may be rotated into the desired position, such that when the needle **20** is subsequently lowered to come into contact with the nozzle seat **18,** it will assume the fixed (predetermined) rotational position. Thus, the force transfer arrangement **26** may be configured to start rotating the needle **20** before it reaches the nozzle seat **18.**

[0028] From the above, it can be understood that, as illustrated in **FIG. 2,** in at least some examples, the needle **20** may present a section with peripheral angled cuts acting as fuel flow channels. Thus, as illustrated in the example of **FIG. 2,** the force transfer arrangement **26** may comprise one or more groves provided on the surface of the needle **20,** the one or more grooves being tilted relative to said longitudinal axis ***X.*** Hereby, when the fuel flows along the needle **20** and on the tilted groove or grooves, the kinetic energy of the fuel will provide for said rotational force.

[0029] **FIG. 3** schematically illustrates a fuel injector **30** according to another example of this disclosure. In this example the force transfer arrangement **32** comprises a separate component which subjects the needle **34** to said rotational force. In particular, **FIG. 3** very schematically indicates that the force transfer arrangement **32** may comprise a torsion spring which is operatively arranged between the nozzle body **36** and the needle **34,** wherein the torsion spring subjects the needle **34** to said rotational force. For example, the force transfer arrangement 32 in the form of a torsion spring may at one end **38** be provided with a pin which is engaged with a hole in the needle **34** (or a component connected to the needle **34**), and may at another end **40** be engaged with a locating dowel **42** which in turn is connected to the nozzle body **36.** It should, however, be understood that other ways of mounting the torsion spring are readily conceivable. It should furthermore be understood that a torsion spring is just one example of a resilient element which can subject the needle **34** to the rotational force. In other examples, the force transfer arrangement **32** may comprise a different resilient element which subjects the needle **34** to the rotational force. For instance, instead of a torsion spring, it would be conceivable to provide protrusions to ends of a compression spring. The ends of the compression spring may be connected to two different parts (e.g., nozzle body and needle) which are rotated relative to each other to bias the compression spring torsionally before the parts are assembled together. As schematically illustrated in **FIG. 3,** also in this example there is provided a rotational stop **24** to limit the rotational play. The force transfer arrangement **32,** in this example the torsion spring, is thus configured to provide to the needle **34** a rotational force relative to the longitudinal axis ***X*** of the needle **34.** This rotational force biases the needle **34** to assume a fixed rotational position at said rotational stop (relative to nozzle body), in the closed state of the fuel injector **30.** If the needle **34** has not yet come to the fixed rotational position when the needle **34** has come into contact with the nozzle seat **18,** the force transfer arrangement **32,** in the form of the torsion spring (or other resilient element), may be configured to rotate the needle **34** to said fixed rotational position.

[0030] It should be noted that although **FIG. 3** illustrates a solid needle **34,** thus indicative of the fuel flowing on the outside of the needle, i.e., between the needle **34** and the nozzle body **36,** it should be understood that other needle configurations may be combinable with a force transfer arrangement comprising a separate component such as a resilient element. For instance, the needle **34** may be provided with internal channels for leading the fuel at least a certain distance inside the needle **34** towards the outlet of the fuel injector **30.**

[0031] **FIG. 4** schematically illustrates an example of a rotational stop **50** which may be implemented in a fuel injector according to at least some examples of this disclosure. In this example, it is very schematically illustrated that the needle **52** may be provided with a protrusion **54** which projects into a slightly oversized recess **56** of the nozzle body **58.** The opposite walls **60, 62** of the recesses **54** limit the rotation of the needle **52** in both the clockwise and counter-clockwise direction. In particular, the protrusion **54** will come in contact with one of the walls **60, 62** depending on in which direction the needle **52** is rotated. In other examples, the needle **52** may instead be provided with a recess into which a protrusion of the nozzle body **58** extends.

[0032] **FIG. 5** schematically illustrates another example of a rotational stop **70** which may be implemented in a fuel injector according to at least some examples of this disclosure. In this example, the rotational stop includes a void **72** formed by a recess of the needle **74** facing a recess of the nozzle body **76.** A ball **78** which has a large enough diameter so as to extend into both recesses that form the void **72,** limits the clockwise and counter-clockwise rotation of the needle **74** relative to the nozzle body **76.**

[0033] In both examples in **FIG. 4** and **FIG. 5,** the rotational stop **50, 70** is achieved by means of the opposing walls of each recess. One of the opposing recesses walls **60, 62** thus forms a first mechanical stop against continued rotation of the needle **52, 74** in one of the clockwise and counter-clockwise direction. The other one of the opposing walls **60, 62** forms a second mechanical stop against continued rotation of the needle **50, 70** in the opposite one of said clockwise and counter-clockwise direction.

[0034] Although **FIG. 4** has mainly been illustrated to show a rotational stop **50,** it should be understood that **FIG. 4** may, in another interpretation, instead be considered to show a very schematic representation of the mutually cooperating axial guide elements discussed previously. Thus, the mutually cooperating guide elements may include one protrusion **54** which cooperates with a recess **56,** wherein the needle **52** is provided with the protrusion **54** and the nozzle body **58** is provided with the recesses. It should be understood that, in some examples, such mutually cooperating axial guide elements may include more protrusions cooperating with respective recesses. Furthermore, the one or more protrusions may, in some examples, be provided on the nozzle body, while the one or more recesses are provided in the needle.

[0035] **FIG. 6** schematically illustrates an internal combustion engine system **80** according to one example of this disclosure. The internal combustion engine system **80** comprises a fuel injector **82,** such as the fuel injector **10, 30** exemplified in **FIG. 2** or **FIG. 3,** or a fuel injector according to any other example of this disclosure. The internal combustion engine system **80** further comprises at least one combustion chamber **84.** The fuel injector **82** is configured to, in the open state, inject fuel **86** into the combustion chamber **84.** However, the fuel injector **82** may be normally in the closed state, and may be configured to become opened by an electrical signal **88** from an engine control module **90,** ECM.

[0036] **FIG. 7** is another, more general, view of **FIG. 1,** according to an example. In particular **FIG. 7** schematically illustrates a fuel injector **100** according to a general example of this disclosure. The fuel injector **100** comprises:

- a nozzle body **102** having an inlet **104** for receiving fuel and an outlet **106** for dispensing received fuel,
- a nozzle seat **108** located within the nozzle body **102,**
- a needle **110** being movable within the nozzle body **102,** selectively towards and away from the nozzle seat **108,** wherein the fuel injector **100** has:

  a closed state in which the needle **110** is mated with the nozzle seat **108** to prevent fuel from being dispensed from the nozzle body **102,** and an open state in which the needle **110** is spaced apart from the nozzle seat **108** to allow fuel to be dispensed from the nozzle body **102,**

  wherein the needle **110** and the nozzle body **102** have mutually cooperating axial guide elements **112, 114** that guide the needle **110** along a geometrical longitudinal axis ***X*** of the needle **110,**

  wherein the guide elements **112, 114** present,

with respect to said longitudinal axis ***X*,** a rotational play between the needle **110** and the nozzle body **102,**
wherein a rotational stop **116** is provided to limit the rotational play,
wherein the fuel injector **100** further comprises:

- a force transfer arrangement **118** configured to provide to the needle **110** a rotational force relative to said longitudinal axis ***X***, the rotational force biasing the needle **110** to assume a fixed rotational position at said rotational stop **116** relative to the nozzle body **102** in said closed state of the fuel injector **110.**

[0037] Example 1: A fuel injector, comprising:

- a nozzle body having an inlet for receiving fuel and an outlet for dispensing received fuel,
- a nozzle seat located within the nozzle body,
- a needle being movable within the nozzle body, selectively towards and away from the nozzle seat, wherein the fuel injector has:

  a closed state in which the needle is mated with the nozzle seat to prevent fuel from being dispensed from the nozzle body, and
  an open state in which the needle is spaced apart from the nozzle seat to allow fuel to be dispensed from the nozzle body,

  wherein the needle and the nozzle body have mutually cooperating axial guide elements that guide the needle along a geometrical longitudinal axis of the needle,
  wherein the guide elements present, with respect to said longitudinal axis, a rotational play between the needle and the nozzle body,
  wherein a rotational stop is provided to limit the rotational play,
  wherein the fuel injector further comprises:

  - a force transfer arrangement configured to provide to the needle a rotational force relative to said longitudinal axis, the rotational force biasing the needle to assume a fixed rotational position at said rotational stop relative to the nozzle body in said closed state of the fuel injector.

[0038] Example 2: The fuel injector of example 1, wherein the force transfer arrangement forms part of the needle in the form of one or more angled peripheral surfaces of the needle, wherein kinetic energy of fuel flowing on said angled peripheral surfaces results in said rotational force being provided to the needle.

[0039] Example 3: The fuel injector of any one of examples 1-2, wherein the force transfer arrangement comprises one or more grooves provided on the surface of the needle, the one or more grooves being tilted relative to said longitudinal axis, wherein fuel flowing along the needle and on the tilted groove(s) provides for said rotational force.

[0040] Example 4: The fuel injector of example 1, wherein the force transfer arrangement comprises a separate component which subjects the needle to said rotational force.

[0041] Example 5: The fuel injector of any one of examples 1 or 4, wherein the force transfer arrangement comprises a resilient element which subjects the needle to said rotational force.

[0042] Example 6: The fuel injector of example 5, wherein the resilient element is in the form of a torsion spring arranged between the nozzle body and the needle, wherein the torsion spring subjects the needle to said rotational force.

[0043] Example 7: The fuel injector of any one of examples 1-6, wherein the mutually cooperating axial guide elements include one or more protrusions cooperating with respective recesses, wherein one of the nozzle body and the needle is provided with said one or more protrusions and the other one of the nozzle body and the needle is provided with said respective recesses.

[0044] Example 8: The fuel injector of any one of examples 1-7, wherein the force transfer arrangement is configured to start rotating the needle before it reaches the nozzle seat.

[0045] Example 9: The fuel injector of any one of examples 1-8, wherein the force transfer arrangement is configured to rotate the needle to said fixed rotational position when the needle has come into contact with the nozzle seat.

[0046] Example 10: The fuel injector of any one of examples 1-9, wherein said rotational stop is a single mechanical stop against continued rotation of the needle in one of a clockwise and counter-clockwise direction.

[0047] Example 11: The fuel injector of any one of examples 1-9, wherein said rotational stop is a first mechanical stop against continued rotation of the needle in one of a clockwise and counter-clockwise direction, wherein the fuel injection further comprises a second mechanical stop against continued rotation of the needle in the opposite one of said clockwise and counter-clockwise direction.

[0048] Example 12: The fuel injector of any one of examples 1-11, wherein the fuel injector is normally in the closed state, and is configured to become opened by an electrical signal from an engine control module, ECM.

[0049] Example 13: The fuel injector of any one of examples 1-12, wherein the needle is solid, wherein the fuel is allowed to flow along the outside of the needle.

[0050] Example 14: The fuel injector of any one of examples 1-12, wherein the needle includes one or more internal channels for allowing the fuel to flow at least partly along the inside of the needle.

[0051] Example 15. The fuel injector of any one of examples 1-14, wherein the rotational stop limits said rotational play to 3° or less, such as 1° or less, for example 0.5° or less.

[0052] Example 16: An internal combustion engine system comprising the fuel injector according to any one of examples 1-15, wherein the fuel injector is configured to, in the open state, inject fuel into a combustion chamber of the internal combustion engine system.

[0053] Example 17: A vehicle comprising the fuel injector according to any one of examples 1-15 or the internal combustion engine system according to example 16.

[0054] The terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, actions, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, actions, steps, operations, elements, components, and/or groups thereof.

[0055] It will be understood that, although the terms first, second, etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

[0056] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element to another element as illustrated in the Figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

[0057] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0058] It is to be understood that the present disclosure is not limited to the aspects described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the present disclosure and appended claims. In the drawings and specification, there have been disclosed aspects for purposes of illustration only and not for purposes of limitation, the scope of the disclosure being set forth in the following claims.

Claims

1. A fuel injector, comprising:

- a nozzle body having an inlet for receiving fuel and an outlet for dispensing received fuel,
- a nozzle seat located within the nozzle body,
- a needle being movable within the nozzle body, selectively towards and away from the nozzle seat, wherein the fuel injector has:

  a closed state in which the needle is mated with the nozzle seat to prevent fuel from being dispensed from the nozzle body, and an open state in which the needle is spaced apart from the nozzle seat to allow fuel to be dispensed from the nozzle body,

  wherein the needle and the nozzle body have mutually cooperating axial guide elements that guide the needle along a geometrical longitudinal axis of the needle,
  wherein the guide elements present, with respect to said longitudinal axis, a rotational play between the needle and the nozzle body,
  wherein a rotational stop is provided to limit the rotational play,
  wherein the fuel injector further comprises:

  - a force transfer arrangement configured to provide to the needle a rotational force relative to said longitudinal axis, the rotational force biasing the needle to assume a fixed rotational position at said rotational stop relative to the nozzle body in said closed state of the fuel injector.

2. The fuel injector of claim 1, wherein the force transfer arrangement forms part of the needle in the form of one or more angled peripheral surfaces of the needle, wherein kinetic energy of fuel flowing on said angled peripheral surfaces results in said rotational force being provided to the needle.

3. The fuel injector of any one of claims 1-2, wherein the force transfer arrangement comprises one or more grooves provided on the surface of the needle, the one or more grooves being tilted relative to said longitudinal axis, wherein fuel flowing along the needle and on the tilted groove(s) provides for said rotational force.

4. The fuel injector of claim 1, wherein the force transfer arrangement comprises a separate component which subjects the needle to said rotational force.

5. The fuel injector of any one of claims 1 or 4, wherein the force transfer arrangement comprises a resilient element which subjects the needle to said rotational force.

6. The fuel injector of claim 5, wherein the resilient element is in the form of a torsion spring arranged between the nozzle body and the needle, wherein the torsion spring subjects the needle to said rotational force.

7. The fuel injector of any one of claims 1-6, wherein the mutually cooperating axial guide elements include one or more protrusions cooperating with respective recesses, wherein one of the nozzle body and the needle is provided with said one or more protrusions and the other one of the nozzle body and the needle is provided with said respective recesses.

8. The fuel injector of any one of claims 1-7, wherein the force transfer arrangement is configured to start rotating the needle before it reaches the nozzle seat.

9. The fuel injector of any one of claims 1-8, wherein the force transfer arrangement is configured to rotate the needle to said fixed rotational position when the needle has come into contact with the nozzle seat.

10. The fuel injector of any one of claims 1-9, wherein said rotational stop is a first mechanical stop against continued rotation of the needle in one of a clockwise and counter-clockwise direction, wherein the fuel injection further comprises a second mechanical stop against continued rotation of the needle in the opposite one of said clockwise and counter-clockwise direction.

11. The fuel injector of any one of claims 1-10, wherein the fuel injector is normally in the closed state, and is configured to become opened by an electrical signal from an engine control module, ECM.

12. An internal combustion engine system comprising the fuel injector according to any one of claims 1-11, wherein the fuel injector is configured to, in the open state, inject fuel into a combustion chamber of the internal combustion engine system.

13. A vehicle comprising the fuel injector according to any one of claims 1-11 or the internal combustion engine system according to claim 12.

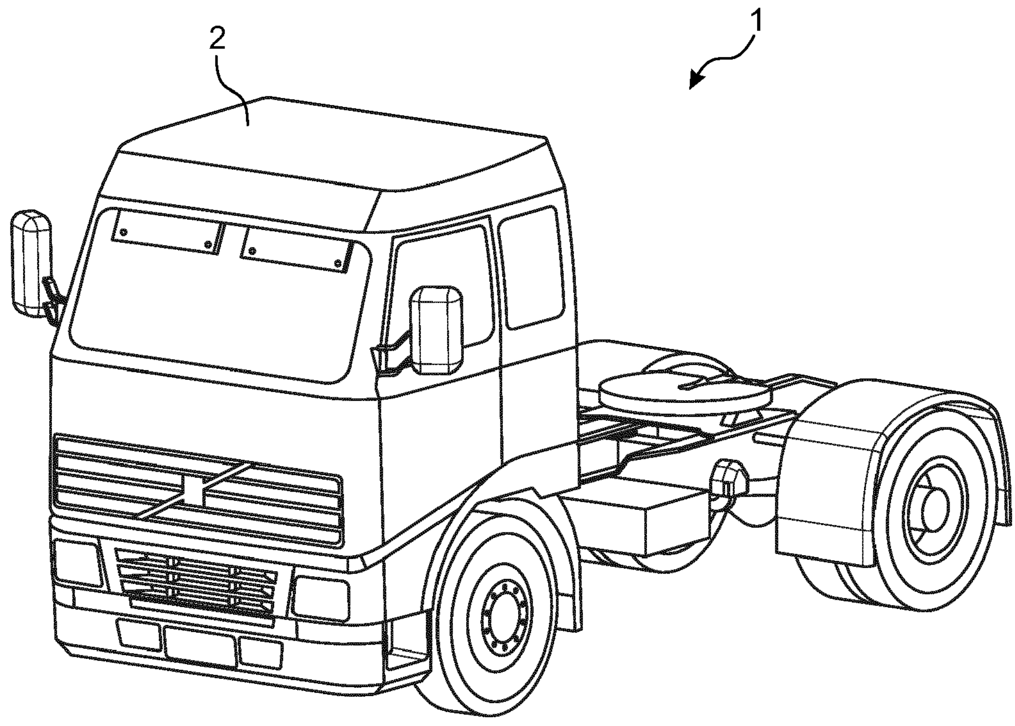

FIG. 1

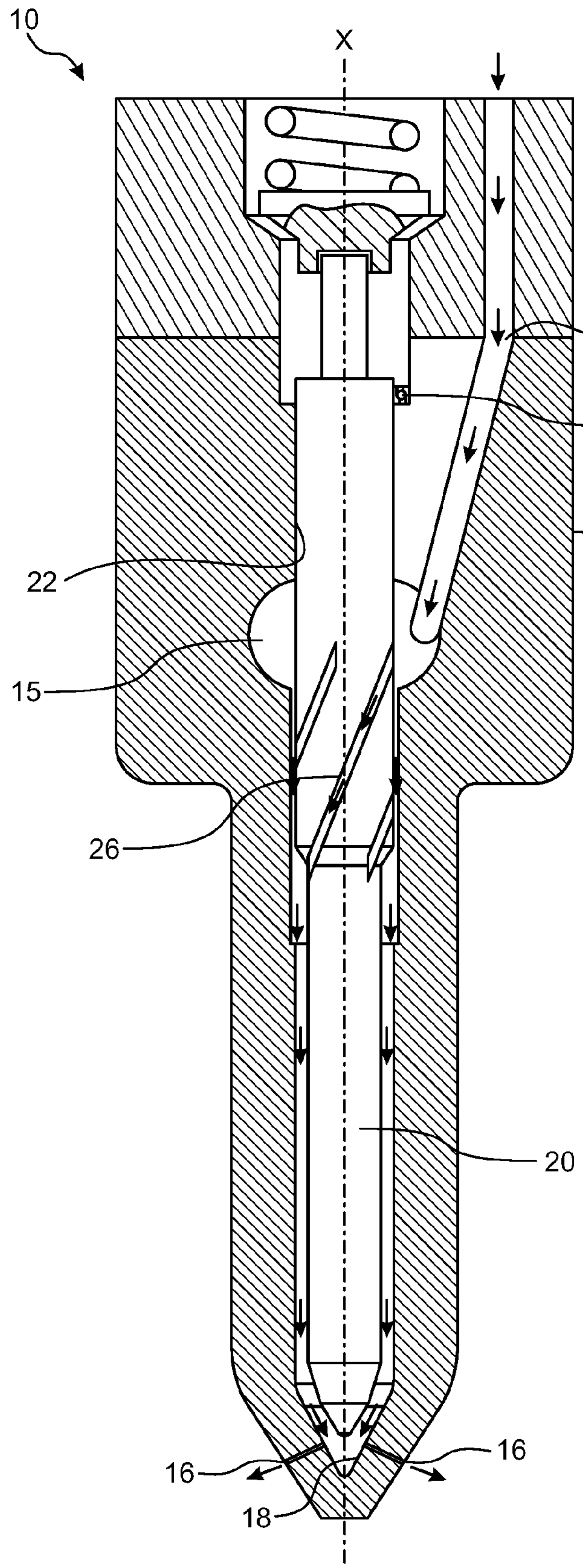

FIG. 2

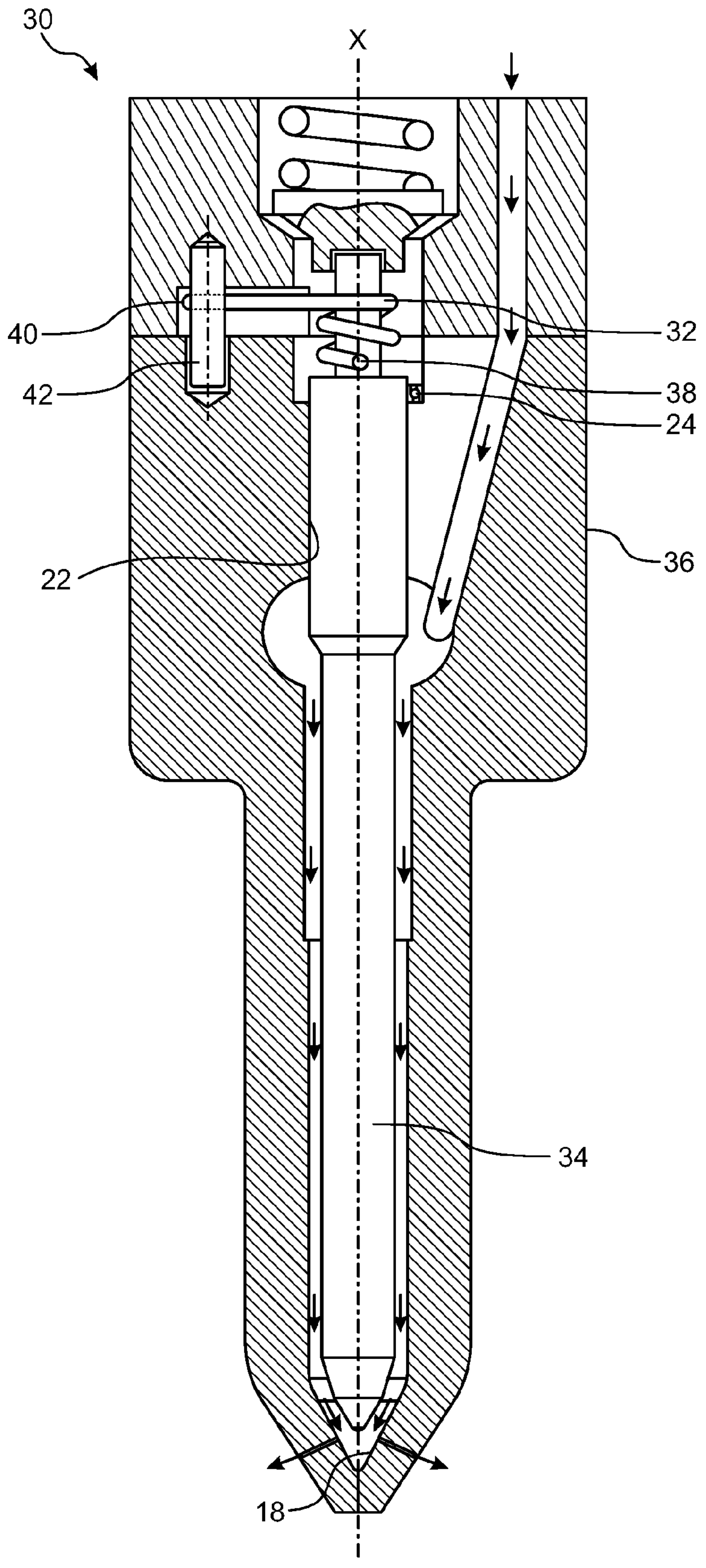

FIG. 3

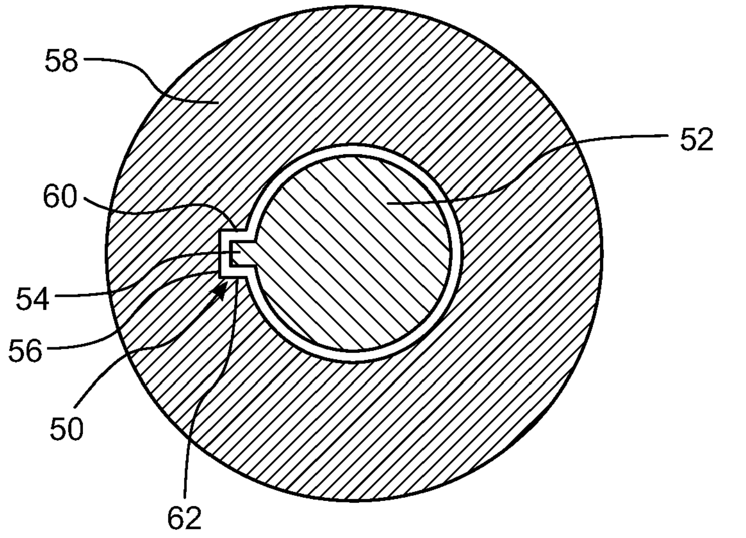

FIG. 4

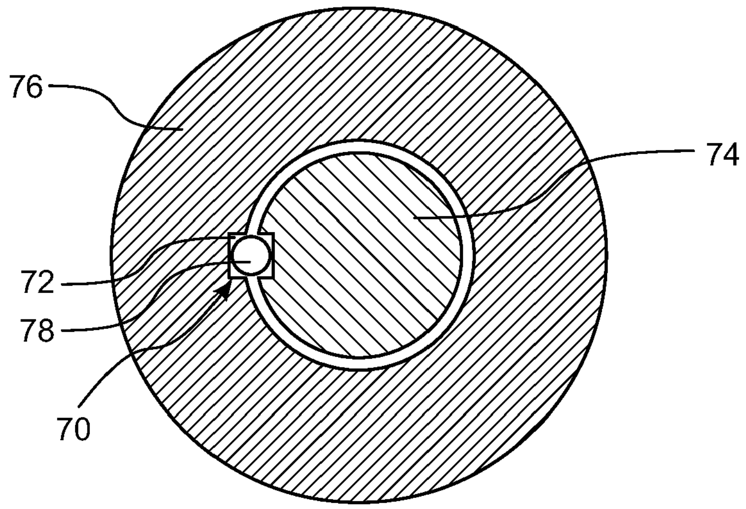

FIG. 5

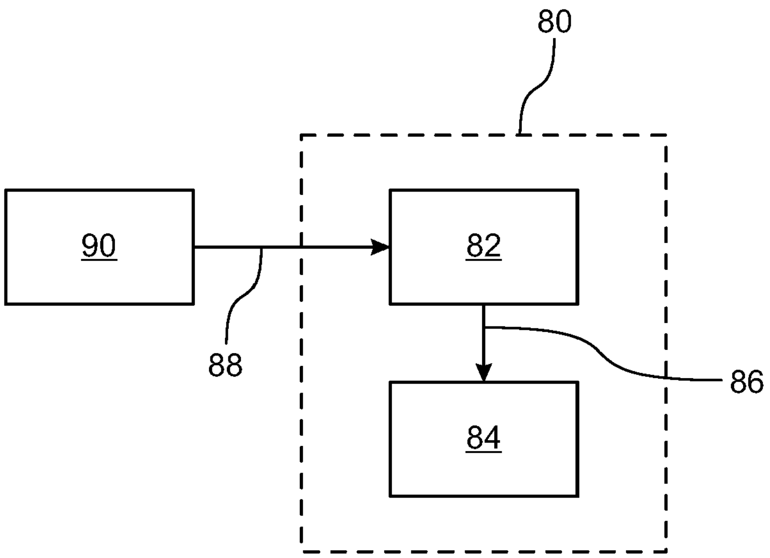

FIG. 6

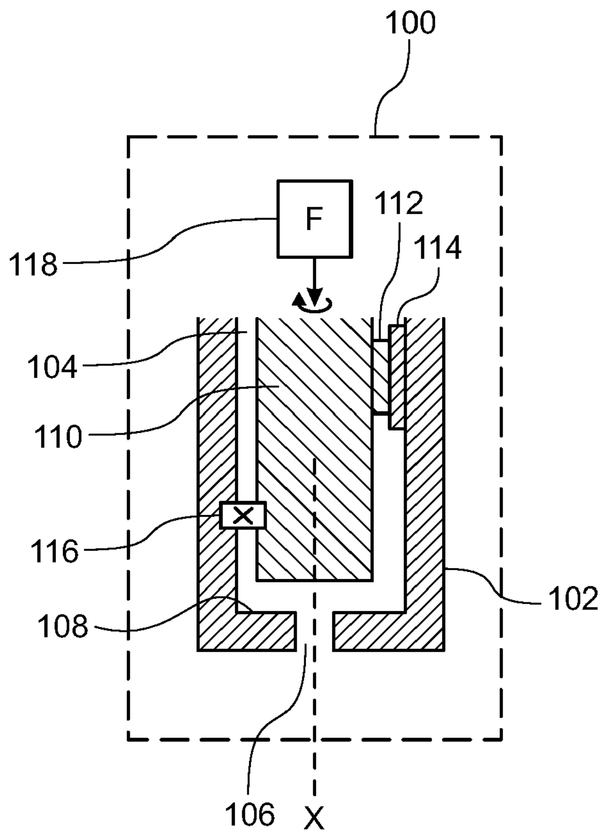

FIG. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 20 8103

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/075619 A1 (PARK JONG-BUM [KR]) 24 April 2003 (2003-04-24) * paragraphs [0020] - [0041]; figures 2-6 *	1,2,4-6, 10-13	INV. F02M61/12 F02M61/16 F02M63/00
X	US 2021/025363 A1 (KIM HYUNG IK [KR] ET AL) 28 January 2021 (2021-01-28) * paragraphs [0052] - [0144]; figures 1-10 *	1-3,7, 10-13	
X	DE 31 39 288 A1 (BOSCH GMBH ROBERT [DE]) 21 April 1983 (1983-04-21) * page 7, paragraph 3rd - page 9, column 1st; figure 1 *	1,2,4-6, 11-13	
X	US 4 382 553 A (THOMA FRANK [DE] ET AL) 10 May 1983 (1983-05-10) * column 3, line 10 - column 3, line 64; figure 1 *	1-3,8,9, 11-13	
X	FR 2 897 396 A1 (RENAULT SAS [FR]) 17 August 2007 (2007-08-17) * page 8, line 28 - page 10, line 17; figures 5-7 *	1,4,5,7, 10-13	TECHNICAL FIELDS SEARCHED (IPC): F02M

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	29 April 2024	Nobre Correia, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 8103

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003075619 A1	24-04-2003	DE 10219137 A1	08-05-2003
		JP 3982304 B2	26-09-2007
		JP 2003139012 A	14-05-2003
		KR 20030033462 A	01-05-2003
		US 2003075619 A1	24-04-2003
US 2021025363 A1	28-01-2021	CN 213540598 U	25-06-2021
		DE 102020209388 A1	28-01-2021
		KR 102180408 B1	18-11-2020
		US 2021025363 A1	28-01-2021
DE 3139288 A1	21-04-1983	DE 3139288 A1	21-04-1983
		JP S58134673 U	10-09-1983
US 4382553 A	10-05-1983	DE 3009219 A1	24-09-1981
		FR 2478208 A1	18-09-1981
		GB 2072262 A	30-09-1981
		US 4382553 A	10-05-1983
FR 2897396 A1	17-08-2007	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82