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(54) **METHOD OF DETERMINING CONDITION OF FUEL PUMP, CONTROL ARRANGEMENT, FUEL SYSTEM, COMBUSTION ENGINE, AND VEHICLE**

(57) A method (100) of determining a condition of a fuel pump (3) of a fuel system (1) of a vehicle (40) is disclosed. The fuel system (1) comprises the fuel pump (3) and a feed pump (5) configured to feed fuel to the fuel pump (3) via a feed conduit (9). The method (100) comprises the steps of operating (110) the feed pump (5) during stand still of the fuel pump (3), obtaining (120) data representative of at least one of a flow and a pressure in the feed conduit (9), and determining (130) a condition of the fuel pump (3) based on the data. The present disclosure further relates to a computer program, a computer-readable medium (200), a control arrangement (21), a fuel system (1), a combustion engine (10), and a vehicle (40) comprising a combustion engine (10).

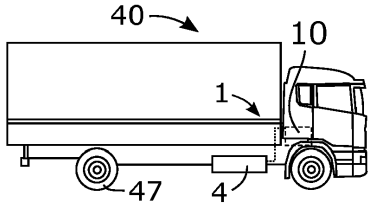

Fig. 1

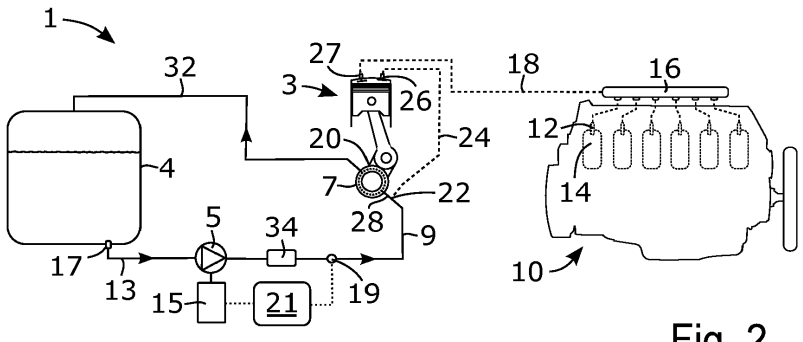

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method of determining a condition of a fuel pump of a fuel system of a vehicle. The present disclosure further relates to a computer program, a computer-readable medium, a control arrangement configured to determine a condition of a fuel pump of a fuel system of a vehicle, a fuel system, an internal combustion engine comprising a fuel system, and a vehicle comprising an internal combustion engine.

BACKGROUND

[0002] Many vehicles are provided with a fuel system which comprises a feed pump and a fuel pump, wherein the feed pump is configured to feed fuel from a fuel tank to the fuel pump. The feed pressure, i.e. the pressure of fuel supplied to the fuel pump, is vital for robustness and life length of the fuel pump. That is, components of the fuel pump may become damaged if there is an issue causing an insufficient feed pressure from the feed pump.

[0003] Insufficient feed pressures may for example arise in situations where the fuel tank is emptied, when one or more conduits is/are clogged, when one or more fuel filter units is/are clogged, and/or upon a malfunction of the feed pump.

[0004] Moreover, some fuel pumps are provided with so called fuel lubricated bearings being lubricated by a supply of fuel from the feed pump. These types of fuel pumps are particularly sensitive to low feed pressures from the feed pump because the lubrication of the bearings is dependent on the supply of fuel from the feed pump. That is, in case of an insufficient feed pressure from the feed pump, the bearings risk becoming damaged upon operation of the fuel pump.

[0005] The breakdown of a fuel pump normally causes standstill of the vehicle and usually leads to costly and time-consuming replacement or repair of the fuel pump. Furthermore, fault diagnostics and troubleshooting of a fuel system is often difficult, time-consuming, and costly. Moreover, in some cases, the fault diagnostics and/or troubleshooting of a fuel system may cause further damage of components of the fuel system.

[0006] In addition, generally, on today's consumer market, it is an advantage if products comprise different features and functions while the products have conditions and/or characteristics suitable for being manufactured and assembled in a cost-efficient manner.

SUMMARY

[0007] It is an object of the present invention to overcome, or at least alleviate, at least some of the above-mentioned problems and drawbacks.

[0008] According to a first aspect of the invention, the object is achieved by a method of determining a condition of a fuel pump of a fuel system of a vehicle. The fuel system comprising the fuel pump and a feed pump configured to feed fuel to the fuel pump via a feed conduit. The method comprises the steps of:

- operating the feed pump during stand still of the fuel pump,
- obtaining data representative of at least one of a flow and a pressure in the feed conduit, and
- determining a condition of the fuel pump based on the data.

[0009] Thereby, a method is provided capable of determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the method comprises the step of determining the condition of the fuel pump based on the data representative of at least one of a flow and a pressure in the feed conduit, which is indicative of the leak rate of fuel past the fuel pump. In turn, the leak rate of fuel past the fuel pump is indicative of the condition of the fuel pump, such as whether one or more components of the fuel pump is/are worn or damaged.

[0010] Moreover, a cost-efficient method is provided for determining the condition of the fuel pump because already existing components of a fuel system can be utilized in one or more of the steps of the method.

[0011] Furthermore, since the feed pump is operated during stand still of the fuel pump, a method is provided having conditions for avoiding further damage of the fuel pump upon determining the condition of the fuel pump.

[0012] In addition, due to the features of the method, conditions are provided for allowing an onboard control arrangement of the vehicle to perform one or more of the steps of the method. In this manner, the need for transporting the vehicle to a service or repair site is circumvented. In addition, due to these features, a method is provided capable of determining the condition of the fuel pump without having to dissemble the fuel pump, the fuel system, or other parts of a vehicle comprising the fuel system.

[0013] Accordingly, a method is provided overcoming, or at least alleviating, at least some of the above-mentioned problems and drawbacks. As a result, the above-mentioned object is achieved.

[0014] The fuel pump comprises one or more fuel lubricated bearings, and the step of determining a condition of the fuel pump comprises the step of:

- determining a condition of the one or more fuel lubricated bearings.

[0015] Thereby, a method is provided capable of determining the condition of the one or more fuel lubricated bearings in a quick, simple, robust, and cost-efficient manner. This is because the method comprises the steps of determining the condition of the fuel pump based on the data representative of at least one of a flow and a

pressure in the feed conduit, which is indicative of the leak rate of fuel past the one or more fuel lubricated bearings of the fuel pump. In turn, the leak rate of fuel past the one or more fuel lubricated bearings of the fuel pump is indicative of the condition of the one or more fuel lubricated bearings, such as whether the one or more fuel lubricated bearings is/are worn or damaged.

[0016] Furthermore, since the feed pump is operated during stand still of the fuel pump, a method is provided having conditions for avoiding further damage of the one or more fuel lubricated bearings upon determining the condition of the one or more fuel lubricated bearings of the fuel pump.

[0017] Moreover, the need for transporting a vehicle comprising the fuel system to a service or repair site is circumvented when determining the condition of the one or more fuel lubricated bearings of the fuel pump. In addition, due to these features, a method is provided capable of determining the condition of the one or more fuel lubricated bearings of the fuel pump without having to dissemble the fuel pump, the fuel system, or other parts of a vehicle comprising the fuel system.

[0018] Optionally, the step of operating the feed pump comprises the step of:

- operating the feed pump to generate a constant feed pressure in the feed conduit,

and wherein the step of obtaining the data comprises the step of:

- obtaining data representative of a flow of fuel in the feed conduit.

[0019] Thereby, a method is provided capable of determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the data representative of a flow of fuel in the feed conduit gives a reliable indication of the leak rate past the fuel pump when the feed pump is operated to generate a constant feed pressure in the feed conduit.

[0020] Optionally, the step/steps of obtaining the data comprises the step of:

- obtaining operational data of the feed pump.

[0021] Thereby, a further simpler and more cost-effective method is provided for determining the condition of the fuel pump while being capable of generating reliable estimations of the condition of the fuel pump. This is because the operational data of the feed pump, during operation thereof, gives a reliable indication of the pressure and flow of fuel in the feed conduit. Moreover, conditions are provided for using already existing components of the fuel system to determine the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner.

[0022] Optionally, the feed pump comprises an electric motor configured to power the feed pump, and wherein the step of obtaining the operational data of the feed pump comprises the step of:

- monitoring electrical data of the electric motor.

[0023] Thereby, a further simpler and more cost-effective method is provided for determining the condition of the fuel pump while being capable of generating reliable estimations of the condition of the fuel pump. This is because the electrical data of the electric motor, during operation thereof, gives a reliable indication of the pressure and flow of fuel in the feed conduit. Moreover, conditions are provided for using already existing components of the fuel system to determine the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner.

[0024] Optionally, the fuel system comprises a pressure sensor configured to sense a pressure in the feed conduit, and wherein the step of obtaining the data comprises the step of:

- obtaining data from the pressure sensor.

[0025] Thereby, a quick, simple, and robust method is provided for determining the condition of the fuel pump. This is because the data from the pressure sensor gives a reliable indication of the pressure and of the flow of fuel in the feed conduit. Moreover, many fuel systems comprise a pressure sensor in the feed conduit between the feed pump and the fuel pump. Thus, also in these embodiments, a method is provided capable of using already existing components of the fuel system for determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner.

[0026] According to a second aspect of the invention, the object is achieved by a computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments of the present disclosure. Since the computer program comprises instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments, a computer program is provided which provides conditions for overcoming, or at least alleviating, at least some of the above-mentioned drawbacks. As a result, the above-mentioned object is achieved.

[0027] According to a third aspect of the invention, the object is achieved by a computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the method according to some embodiments of the present disclosure. Since the computer-readable medium comprises instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments, a computer-readable medium is provided which provides conditions for overcoming, or at

least alleviating, at least some of the above-mentioned drawbacks. As a result, the above-mentioned object is achieved.

[0028] According to a fourth aspect of the invention, the object is achieved by a control arrangement configured to determine a condition of a fuel pump of a fuel system of a vehicle, wherein the fuel system comprises the fuel pump, a feed pump, and a feed conduit, wherein the feed pump is configured to feed fuel to the fuel pump via the feed conduit, and wherein the control arrangement is configured to:

- operate the feed pump during stand still of the fuel pump,
- obtain data representative of at least one of a flow and a pressure in the feed conduit, and
- determine a condition of the fuel pump based on the data.

[0029] Thereby, a control arrangement is provided capable of determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the control arrangement is configured to determine the condition of the fuel pump based on the data representative of at least one of a flow and a pressure in the feed conduit, which is indicative of the leak rate of fuel past the fuel pump. In turn, the leak rate of fuel past the fuel pump is indicative of the condition of the fuel pump, such as whether one or more components of the fuel pump is/are worn or damaged.

[0030] Moreover, a control arrangement is provided capable of determining the condition of the fuel pump in a cost-efficient manner because already existing components of a fuel system can be utilized by the control arrangement when determining the condition of the fuel pump.

[0031] Furthermore, since the control arrangement is configured to operate the feed pump during stand still of the fuel pump, a control arrangement is provided having conditions for avoiding further damage of the fuel pump upon determining the condition of the fuel pump.

[0032] In addition, due to the features of the control arrangement, conditions are provided for allowing the control arrangement to be arranged on a vehicle when performing the determining of the condition of the fuel pump. In this manner, the need for transporting the vehicle to a service or repair site is circumvented. In addition, due to these features, a control arrangement is provided capable of determining the condition of the fuel pump in a manner circumventing the need for dissembling the fuel pump, the fuel system, or other parts of a vehicle comprising the fuel system.

[0033] Accordingly, a control arrangement is provided overcoming, or at least alleviating, at least some of the above-mentioned problems and drawbacks. As a result, the above-mentioned object is achieved.

[0034] It will be appreciated that the various embodiments described for the method are all combinable with the control arrangement as described herein. That is, the control arrangement may be configured to perform any one of the method steps of the method according to the first aspect of the invention.

[0035] According to a fifth aspect of the invention, the object is achieved by a fuel system comprising a fuel pump, a feed pump, and a feed conduit, wherein the feed pump is configured to feed fuel to the fuel pump via the feed conduit, and wherein the fuel system comprises a control arrangement configured to determine a condition of the fuel pump of the fuel system, wherein the control arrangement is configured to:

- operate the feed pump during stand still of the fuel pump,
- obtain data representative of at least one of a flow and a pressure in the feed conduit, and
- determine a condition of the fuel pump based on the data.

[0036] Thereby, a fuel system is provided capable of determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner. Moreover, a fuel system is provided capable of determining the condition of the fuel pump in a cost-efficient manner because simple, low cost, and already existing components of the fuel system can be utilized by the control arrangement when determining the condition of the fuel pump.

[0037] Furthermore, since the control arrangement of the fuel system is configured to operate the feed pump during stand still of the fuel pump, a fuel system is provided having conditions for avoiding further damage of the fuel pump upon determining the condition of the fuel pump.

[0038] In addition, due to the features of the fuel system, the need for transporting the vehicle to a service or repair site is circumvented. In addition, due to these features, a fuel system is provided capable of determining the condition of the fuel pump in a manner circumventing the need for dissembling the fuel pump, the fuel system, or other parts of a vehicle comprising the fuel system.

[0039] Accordingly, a fuel system is provided overcoming, or at least alleviating, at least some of the above-mentioned problems and drawbacks. As a result, the above-mentioned object is achieved.

[0040] The fuel pump comprises one or more fuel lubricated bearings, and the control arrangement is configured to determine a condition of the one or more fuel lubricated bearings based on the data.

[0041] Thereby, a fuel system is provided capable of determining the condition of the one or more fuel lubricated bearings in a quick, simple, robust, and cost-efficient manner. Furthermore, since the feed pump is operated during stand still of the fuel pump, a fuel system is provided having conditions for avoiding further damage of the one or more fuel lubricated bearings upon determining the condition of the one or more fuel lubricated bearings of the fuel pump.

[0042] Moreover, the need for transporting a vehicle comprising the fuel system to a service or repair site is circumvented when determining the condition of the one or more fuel lubricated bearings of the fuel pump. In addition, due to these features, a fuel system is provided capable of determining the condition of the one or more fuel lubricated bearings of the fuel pump without having to dissemble the fuel pump, the fuel system, or other parts of a vehicle comprising the fuel system.

[0043] Optionally, the control arrangement is configured to operate the feed pump to generate a constant feed pressure in the feed conduit, and to obtain data representative of a flow of fuel in the feed conduit. Thereby, a fuel system is provided capable of determining the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the data representative of a flow of fuel in the feed conduit gives a reliable indication of the leak rate past the fuel pump when the feed pump is operated to generate a constant feed pressure in the feed conduit.

[0044] Optionally, the control arrangement is configured to obtain operational data of the feed pump. Thereby, a further simpler and more cost-effective fuel system is provided for determining the condition of the fuel pump while being capable of generating reliable estimations of the condition of the fuel pump. This is because the operational data of the feed pump, during operation thereof, gives a reliable indication of the pressure and flow of fuel in the feed conduit. Moreover, conditions are provided for using already existing components of the fuel system to determine the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner.

[0045] Optionally, the feed pump comprises an electric motor configured to power the feed pump, and wherein the control arrangement is configured to monitor electrical data of the electric motor. Thereby, a further simpler and more cost-effective fuel system is provided for determining the condition of the fuel pump while being capable of generating reliable estimations of the condition of the fuel pump. This is because the electrical data of the electric motor, during operation thereof, gives a reliable indication of the pressure and flow of fuel in the feed conduit. Moreover, conditions are provided for using already existing components of the fuel system to determine the condition of the fuel pump in a quick, simple, robust, and cost-efficient manner.

[0046] Optionally, the fuel system comprises a pressure sensor configured to sense a pressure in the feed conduit, and wherein the control arrangement is configured to obtain data from the pressure sensor. Thereby, a fuel system is provided capable of determining the condition of the fuel pump in a quick, simple, and robust manner. This is because the data from the pressure sensor gives a reliable indication of the pressure and of the flow of fuel in the feed conduit.

[0047] According to a sixth aspect of the invention, the object is achieved by an internal combustion engine comprising a fuel system according to some embodiments of the present disclosure.

[0048] Since the internal combustion engine comprises a fuel system according to some embodiments, an internal combustion engine is provided overcoming, or at least alleviating, at least some of the above-mentioned problems and drawbacks. As a result, the above-mentioned object is achieved.

[0049] Optionally, the internal combustion engine is a compression ignition engine.

[0050] According to a seventh aspect of the invention, the object is achieved by a vehicle comprising an internal combustion engine according to some embodiments of the present disclosure. Since the vehicle comprises an internal combustion engine according to some embodiments, a vehicle is provided overcoming, or at least alleviating, at least some of the above-mentioned problems and drawbacks. As a result, the above-mentioned object is achieved.

[0051] Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0052] Various aspects of the invention, including its particular features and advantages, will be readily understood from the example embodiments discussed in the following detailed description and the accompanying drawings, in which:

Fig. 1 illustrates a vehicle according to some embodiments of the present disclosure,
Fig. 2 schematically illustrates an internal combustion engine and a fuel system of the vehicle illustrated in Fig. 1,
Fig. 3 illustrates a method of determining a condition of a fuel pump of a fuel system of a vehicle, and
Fig. 4 illustrates computer-readable medium.

DETAILED DESCRIPTION

[0053] Aspects of the present invention will now be described more fully. Like numbers refer to like elements throughout. Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity.

[0054] Fig. 1 illustrates a vehicle 40 according to some embodiments of the present disclosure. According to the illustrated embodiments, the vehicle 40 is a truck, i.e. a type of heavy vehicle. According to further embodiments, the vehicle 40, as referred to herein, may be another type of heavy or lighter type of manned or unmanned vehicle for land or water based propulsion such as a lorry, a bus, a construction vehicle, a tractor, a car, a ship, a boat, or the like.

[0055] The vehicle 40 comprises an internal combustion engine 10. According to the illustrated embodiments,

the internal combustion engine 10 is configured to provide motive power to the vehicle 40 via wheels 47 of the vehicle 40. The vehicle 40 may comprise one or more electric propulsion motors in addition to the internal combustion engine 10 for providing motive power to the vehicle 40. Thus, the vehicle 40 may comprise a so called hybrid electric powertrain comprising one or more electric propulsion motors in addition to the internal combustion engine 10 for providing motive power to the vehicle 40.

[0056] In Fig. 1, a fuel system 1 of the vehicle 40 is schematically indicated. The fuel system 1 is configured to supply fuel from a fuel tank 4 of the vehicle 40 to the internal combustion engine 10.

[0057] Fig. 2 schematically illustrates the internal combustion engine 10 and the fuel system 1 of the vehicle 40 illustrated in Fig. 1. Moreover, in Fig. 2, the fuel tank 4 of the vehicle 40 is illustrated. The fuel tank 4 may be comprised in the fuel system 1 as referred to herein. Below, simultaneous reference is made to Fig. 1 and Fig. 2, if not indicated otherwise.

[0058] According to embodiments herein, the fuel tank 4 is configured to accommodate a liquid fuel. According to the illustrated embodiments, the internal combustion engine 10 is a diesel engine, i.e. a type of compression ignition engine, configured to operate on diesel or a diesel-like fuel, such as biodiesel, biomass to liquid (BTL), or gas to liquid (GTL) diesel. Thus, according to these embodiments, the fuel tank 4 is configured to accommodate diesel or a diesel-like fuel. Diesel-like fuels, such as biodiesel, can be obtained from renewable sources such as vegetable oil which mainly comprises fatty acid methyl esters (FAME). Diesel-like fuels can be produced from many types of oils, such as rapeseed oil (rapeseed methyl ester, RME) and soybean oil (soy methyl ester, SME).

[0059] According to further embodiments, the internal combustion engine 10 may an Otto engine with a spark-ignition device, wherein the Otto engine may be configured to run on petrol, alcohol, similar volatile fuels, or combinations thereof. Thus, according to such embodiments, the fuel tank 4 is configured to accommodate petrol, alcohol, similar volatile fuels, or combinations thereof. Alcohol, such as ethanol, can be derived from renewable biomass.

[0060] The internal combustion engine 10 is in some places herein referred to as the combustion engine 10, for reasons of brevity and clarity.

[0061] The fuel system 1 comprises a fuel pump 3, a feed pump 5, and a feed conduit 9, wherein the feed pump 5 is configured to feed fuel from the fuel tank 4 to the fuel pump 3 via the feed conduit 9. The feed pump 5 is thus fluidly connected to the fuel pump 3 via the feed conduit 9. Moreover, the feed pump 5 is fluidly connected to the fuel tank 4 via a line 13 connected to an outlet 17 of the fuel tank 4. The feed pump 5 is thus fluidly connected to the fuel tank 4 and to the fuel pump 3 and is configured to pump fuel in a direction from the fuel tank 4 to the fuel pump 3.

[0062] According to the illustrated embodiments, the feed pump 5 comprises an electric motor 15 configured to power the feed pump 5. The vehicle 40 may comprise an electric system comprising one or more batteries, wherein the electric motor 15 is powered via the electric system. According to further embodiments, the feed pump 5 may comprise another type of actuator for powering the feed pump 5, such as a pneumatic, hydraulic, and/or mechanical actuator. The feed pump 5 may also be referred to as a "low pressure pump", a "low pressure fuel pump" or the like and may be configured to generate a pressure of fuel in the feed conduit 9 within the range of 0 - 15 bar. The feed pump 5 may be a positive displacement pump, such as a gear pump.

[0063] According to the illustrated embodiments, the fuel pump 3 is a piston pump, i.e. a type of positive displacement pump. According to further embodiments, the fuel pump 3 may be another type of positive displacement pump. The fuel pump 3 may also be referred to as a "high pressure pump", a "high pressure fuel pump" or the like and may be configured to generate a pressure of fuel within the range of 150 - 3 000 bar. The fuel pump 3 is configured to pump fuel to fuel injectors 12 of the combustion engine 10. According to the illustrated embodiments, the fuel injectors 12 are arranged to inject fuel directly into cylinders 14 of the combustion engine 10. The combustion engine 10 according to the embodiments illustrated in Fig. 2 comprises six cylinders 14 and one fuel injector 12 per cylinder 14. However, for reasons of brevity and clarity, only one of the fuel injectors 12 has been provided with the reference sign "12" in Fig. 2 and only one of the cylinders 14 of the combustion engine 10 has been provided with the reference sign "14" in Fig. 2.

[0064] According to further embodiments, the combustion engine 10 may comprise another number of cylinders 14 and another number of fuel injectors 12 per cylinder 14. Moreover, according to some embodiments, the fuel system 1 may comprise one or more fuel injectors configured to inject fuel into an air inlet of the combustion engine 10 as an alternative to fuel injectors 12 configured to inject fuel into the cylinders 14 or in addition to the fuel injectors 12 configured to inject fuel into the cylinders 14. According to the illustrated embodiments, the fuel system 1 comprises a common rail 16, wherein the fuel pump 3 is configured to pump fuel to the common rail 16 via an outlet line 18 connected to an outlet 27 of the fuel pump 3, and wherein the fuel injectors 12 of the combustion engine 10 is fluidly connected to the common rail 16.

[0065] The fuel system 1 comprises a control arrangement 21. As is further explained herein, the control arrangement 21 is configured to determine a condition of a fuel pump 3 of the fuel system 1 by operating the feed pump 5 during stand still of the fuel pump 3, obtaining data representative of at least one of a flow and a pressure in the feed conduit 9, and determining the condition of the fuel pump 3 based on the data. Thereby, the control arrangement 21 can determine the condition of the fuel pump 3 in a quick, simple, robust, and cost-efficient manner, as is further explained herein.

[0066] The condition of the fuel pump 3, as referred to herein, may comprise a degree of wear and/or a degree of damage of one or more components of the fuel pump 3. According to the illustrated embodiments, the control arrangement 21 is configured to operate the feed pump 5 by activating operation of the electric motor 15 of the feed pump 5. According to further embodiments, the control arrangement 21 may be configured to operate the feed pump 5 in another manner, such as by activating operation of a pneumatic, hydraulic, and/or mechanical actuator configured to power the feed pump 5. The control arrangement 21 may ensure that the fuel pump 3 is at standstill, i.e. is not operating, by ensuring that the combustion engine 10 is at standstill, i.e. is not operating. The control arrangement 21 may utilize data from an engine control unit of the combustion engine 10, or from other type of control unit or sensor of the vehicle 40, to verify whether the combustion engine 10 is at standstill or not.

[0067] In the following, details of the fuel system 1 according to the illustrated embodiments will be explained. However, the fuel system 1 may have a different layout than the fuel system 1 according to the illustrated embodiments. According to the illustrated embodiments, the fuel pump 3 comprises a number of fuel lubricated bearings 7. In Fig. 2, one fuel lubricating bearing 7 is schematically indicated. The number of fuel lubricated bearings 7 is configured to support a rotating component of the fuel pump 3, such as a crankshaft 20 of the fuel pump 3 or another type of shaft or rotating component of the fuel pump 3. The fuel lubricated bearings 7 may be of plain bearing type.

[0068] The fuel system 1 comprises a fuel filter 34 arranged in the feed conduit 9 between the feed pump 5 and the fuel pump 3. Moreover, as can be seen in Fig. 2, the feed conduit 9 between the feed pump 5 and the fuel pump 3 comprises a junction 22 separating the feed conduit 9 into an inlet line 24 fluidly connected to an inlet 26 of the fuel pump 3 and into a bearing inlet line 28 fluidly connected to the number of fuel lubricated bearings 7 of the fuel pump 3. Moreover, the fuel system 1 comprises a fuel return line 32 configured to return fuel from the number of fuel lubricated bearings 7 to the fuel tank 4. According to further embodiments, the fuel return line 32 may be configured to return fuel from the number of fuel lubricated bearings 7 to another portion of the fuel system 1 preferably at a position upstream of the feed pump 5.

[0069] As understood from the above described, during operation of the combustion engine 10 comprising the fuel system 1, according to the illustrated embodiments, the feed pump 5 pumps fuel to the fuel pump 3, wherein a partial flow of the fuel is guided through the number of fuel lubricated bearings 7 via the bearing inlet line 28. Most of the fuel may be guided to the inlet 26 of the fuel pump 3 via the inlet line 24. The partial flow of fuel being guided through the number of fuel lubricated bearings 7 may, during normal operation of the combustion engine 10 comprising the fuel system 1, constitute a few percent of the total flow of fuel through the feed line 9 or a larger percentage of the total flow of fuel through the feed line 9. According to further embodiments, all fuel may be guided through the number of fuel lubricated bearings 7 before reaching the inlet 26 of the fuel pump 3.

[0070] Due to the flow of fuel through the number of fuel lubricated bearings 7, the number of fuel lubricated bearings 7 are lubricated and cooled. However, the number of fuel lubricated bearings 7 are sensitive of low feed pressures from the feed pump 5. Low/insufficient feed pressures may for example be arise in situations where the fuel tank 4 is emptied, when one or more conduits of the fuel system 1 is/are clogged, when one or more fuel filter units 34 is/are clogged, and/or upon a malfunction of the feed pump 5. An insufficient feed pressure from the feed pump 5 results in an insufficient flow of fuel through the number of fuel lubricated bearings 7 which may cause premature wear and/or damage of the number of fuel lubricated bearings 7.

[0071] According to the embodiments illustrated in Fig. 2, the control arrangement 21 is configured to determine a condition of the number of fuel lubricated bearings 7 of the fuel pump 3 by operating the feed pump 5 during stand still of the fuel pump 3, obtaining data representative of at least one of a flow and a pressure in the feed conduit 9, and determine the condition of the number of fuel lubricated bearings 7 of the fuel pump 3 based on the data. Thereby, the control arrangement 21 is capable of determining the condition of the number of fuel lubricated bearings 7 of the fuel pump 3 in a quick, simple, robust, and cost-efficient manner, as is further explained herein.

[0072] During the procedure of determining the condition of the number of fuel lubricated bearings 7 of the fuel pump 3, the feed pump 5 is pumping fuel through the feed conduit 9, the bearing inlet line 28, and the number of fuel lubricated bearings 7 and back to the fuel tank 4 via the fuel return line 32. Since no fuel is flowing through the inlet line 24 and the outlet line 18 of the fuel pump 3 during this procedure, these lines have been illustrated in dashed lines in Fig. 2. No fuel is flowing through the inlet line 24 and the outlet line 18 of the fuel pump 3 during the procedure because the fuel pump 3 is at stand still during the procedure and because the fuel pump 3 is a positive displacement pump.

[0073] The condition of the number of fuel lubricated bearings 7 of the fuel pump 3, as referred to herein, may comprise a degree of wear and/or a degree of damage of the number of fuel lubricated bearings 7 of the fuel pump 3. The flow and pressure in the feed conduit 9 during this procedure is indicative of the degree of wear and/or a degree of damage of the number of fuel lubricated bearings 7 of the fuel pump 3 because these aspects affect the flow resistance of fuel through the number of fuel lubricated bearings 7.

[0074] As an example, a worn and/or damaged fuel lubricated bearing 7 may reduce the flow resistance of

fuel through the fuel lubricated bearing 7. A reduced flow resistance of fuel through the fuel lubricated bearing 7 reduces the pressure of fuel in the feed conduit 9 and increases the flow of fuel through the feed conduit 9 given a certain pumping power or a certain pumping rate of the feed pump 5. Thus, by analysing the data representative of at least one of a flow and a pressure in the feed conduit 9 during operation of the feed pump 5 upon standstill of the fuel pump 3, the condition of the fuel pump 3 can be determined in a quick, simple, robust, and cost-efficient manner. Furthermore, since the procedure is performed during stand still of the fuel pump 3, further damage/wear of the fuel pump 3 can be avoided during the procedure.

[0075] According to some embodiments of the herein described, the control arrangement 21 may be configured to operate the feed pump 5 to generate a constant feed pressure in the feed conduit 9 and to obtain data representative of a flowrate of fuel in the feed conduit 9. Thereby, the control arrangement 21 is capable of determining the condition of the number of fuel lubricated bearings 7 of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the data representative of a flowrate of fuel in the feed conduit 9 gives a reliable indication of the flowrate of fuel through the number of fuel lubricated bearings 7 of the fuel pump 3 and thus also of the condition of the number of fuel lubricated bearings 7 of the fuel pump 3.

[0076] Moreover, according to some embodiments of the herein described, the control arrangement 21 may be configured to obtain the data by obtaining/monitoring operational data of the feed pump 5. The data representative of at least one of a flow and a pressure in the feed conduit 9 may thus comprise operational data of the feed pump 5. The operational data of the feed pump 5 may comprise one or more of the rotational speed of the feed pump 5, the power of the feed pump 5, and the work performed by the feed pump 5. Thus, the data representative of a flowrate of fuel in the feed conduit 9 and the pressure of fuel in the feed conduit 9 may be obtained by obtaining/monitoring operational data of the feed pump 5. Thereby, the control arrangement 21 is capable of determining the condition of the number of fuel lubricated bearings 7 of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the operational data of the feed pump 5 gives a reliable indication of the flowrate of fuel through the number of fuel lubricated bearings 7 of the fuel pump 3 and thus also of the condition of the number of fuel lubricated bearings 7 of the fuel pump 3.

[0077] Moreover, according to some embodiments of the herein described, the control arrangement 21 may be configured to obtain the data by obtaining/monitoring electrical data of the electric motor 15. The data representative of at least one of a flow and a pressure in the feed conduit 9 may thus comprise electrical data of the electric motor 15. The electrical data of the electric motor 15 may comprise one or more of an electric supply current of the electric motor 15 and an electric supply voltage of the electric motor 15. Thus, the data representative of a flowrate of fuel in the feed conduit 9 and the pressure of fuel in the feed conduit 9 may be obtained by obtaining/monitoring electrical data of the electric motor 15. Thereby, the control arrangement 21 is capable of determining the condition of the number of fuel lubricated bearings 7 of the fuel pump in a quick, simple, robust, and cost-efficient manner. This is because the electrical data of the electric motor 15 gives a reliable indication of the flowrate of fuel through the number of fuel lubricated bearings 7 of the fuel pump 3 and thus also of the condition of the number of fuel lubricated bearings 7 of the fuel pump 3. Thus, by obtaining/monitoring electrical data of the electric motor 15, a further simpler and more cost-effective fuel system 1 is provided for determining the condition of the fuel pump 3 while being capable of giving a clear indication of the condition of the fuel pump 3.

[0078] According to the illustrated embodiments, the fuel system 1 comprises a pressure sensor 19. The pressure sensor 19 is configured to sense a current pressure in the feed conduit 9 between the feed pump 5 and the fuel pump 3. According to these embodiments, the control arrangement 21 may be configured to obtain the data representative of at least one of a flow and a pressure in the feed conduit 9 by obtaining data from the pressure sensor 19. The data representative of at least one of a flow and a pressure in the feed conduit 9 may thus comprise pressure data obtained from the pressure sensor 19. In this manner, the condition of the fuel pump 3 can be determined in a quick, simple, and robust manner. This is because the pressure data from the pressure sensor 19 gives a reliable indication of the pressure and of the flow of fuel in the feed conduit 9.

[0079] According to the illustrated embodiments, the control arrangement 21 of the fuel system 1 is arranged on the vehicle 40 comprising the fuel system 1. Thereby, the control arrangement 21 is capable of performing the above described procedure occasionally, regularly and/or upon a triggering event, without having to transport the vehicle 40 to a service or repair site and without having to transport a technician to the vehicle 40. The control arrangement 21 may be implemented in an on-board diagnostic system configured to determine the condition of the fuel pump 3 occasionally, regularly and/or upon a triggering event.

[0080] The triggering event may for example comprise a detection of an unexpected low pressure in the feed conduit 9, for example sensed by the pressure sensor 19. That is, according to such embodiments, the control arrangement 21 may sense a current pressure in the feed conduit 9 during operation of the combustion engine 10. If the sensed current pressure in the feed conduit 9 falls below a threshold pressure, the control arrangement 21 may subsequently trigger the above described procedure for determining the condition of the fuel pump 3.

[0081] The control arrangement 21 may determine that the condition of the fuel pump 3 is normal/undamaged if the data indicates that the flow of fuel through the feed

conduit 9 is within a predetermined range and/or if the data indicates that the pressure of fuel in the feed conduit 9 is within a predetermined pressure range when operating the feed pump 5. Likewise, the control arrangement 21 may determine that an operational fault has occurred in the fuel pump 3 if the data indicates that the flow of fuel through the feed conduit 9 exceeds the predetermined range and/or the data indicates that the pressure of fuel in the feed conduit 9 is below the predetermined pressure range when operating the feed pump 5. The operational fault, referred to above, may comprise wear or damage of one or more components of the fuel pump 3, such as the number of fuel lubricated bearings 7 of the fuel pump 3.

[0082] If it is determined that an operational fault has occurred in the fuel pump 3, the information may be outputted in the form of an activation of the light emitting unit in a driver environment of the vehicle 40, a displaying of a symbol, and/or text, on a display arranged in the driver environment of the vehicle 40, an activation of a restricted so called limp home mode of the vehicle 40, and/or a sending of a message to an external unit, such as another control arrangement of the vehicle 40, a diagnostics tool, and/or a service and repair centre.

[0083] Furthermore, according to some embodiments of the herein described, at least part of the control arrangement 21, as referred to herein, may be implemented in an off-board diagnostics tool, i.e. in an external device, connectable to the vehicle 40 comprising the fuel system 1. Moreover, according to further embodiments, the control arrangement 21, as referred to herein, may be configured to communicate with an off-board diagnostics tool. According to such embodiments, the off-board diagnostics tool may trigger the control arrangement 21 to perform the procedure of determining the condition of the fuel pump 3 of the fuel system 1.

[0084] Fig. 3 illustrates a method 100 of determining a condition of a fuel pump of a fuel system of a vehicle. The vehicle may be a vehicle 40 according to the embodiments illustrated in Fig. 1 and the fuel system may be a fuel system 1 according to the embodiments illustrated in Fig. 2. Therefore, in the following, simultaneous reference is made to Fig. 1 - Fig. 3, if not indicated otherwise. The method 100 is a method of determining a condition of a fuel pump 3 of a fuel system 1 of a vehicle 40, wherein the fuel system 1 comprises the fuel pump 3 and a feed pump 5 configured to feed fuel to the fuel pump 3 via a feed conduit 9. The method 100 comprises the steps of:

- operating 110 the feed pump 5 during stand still of the fuel pump 3,
- obtaining 120 data representative of at least one of a flow and a pressure in the feed conduit 9, and
- determining 130 a condition of the fuel pump 3 based on the data.

[0085] The step of obtaining 120 the data may be performed during the step of operating 110 the feed pump 5.

[0086] The fuel pump 3 comprises one or more fuel lubricated bearings 7, and the step of determining 130 a condition of the fuel pump 3 comprises the step of:

- determining 132 a condition of the one or more fuel lubricated bearings 7 based on the data.

[0087] As indicated in Fig. 3, the step of operating 110 the feed pump 5 may comprise the step of:

- operating 112 the feed pump 5 to generate a constant feed pressure in the feed conduit 9,

and wherein the step of obtaining 120 the data comprises the step of:

- obtaining 122 data representative of a flow of fuel in the feed conduit 9.

[0088] Moreover, according to some embodiments, the step/steps of obtaining 120, 122 the data may comprise the step of:

- obtaining 124 operational data of the feed pump 5.

[0089] According to some embodiments, the feed pump 5 comprises an electric motor 15 configured to power the feed pump 5, and wherein the step of obtaining 124 the operational data of the feed pump 5 comprises the step of:

- monitoring 126 electrical data of the electric motor 15.

[0090] Moreover, according to some embodiments, the fuel system 1 comprises a pressure sensor 19 configured to sense a current pressure in the feed conduit 9, and wherein the step of obtaining 120 the data comprises the step of:

- obtaining 128 data from the pressure sensor 19.

[0091] It will be appreciated that the various embodiments described for the method 100 are all combinable with the control arrangement 21 as described herein. That is, the control arrangement 21 may be configured to perform any one of the method steps 110, 112, 120, 122, 124, 126, 128, 130, and 132 of the method 100.

[0092] **Fig. 4** illustrates computer-readable medium 200 comprising instructions. Below, simultaneous reference is made to Fig. 1 - Fig. 4, if not indicated otherwise. The computer-readable medium 200 comprises instructions which, when executed by a computer, cause the computer to carry out the method 100 according to some embodiments.

[0093] According to some embodiments, the computer-readable medium 200 comprises a computer pro-

gram comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method 100 according to some embodiments.

[0094] The control arrangement 21 may be connected to one or more components of the fuel system 1, and/or one or more components of the vehicle 40, in order to perform the method 100 illustrated in Fig. 3. According to some embodiments, control arrangement 21 comprises a control unit. One skilled in the art will appreciate that the method 100 of determining the condition of the fuel pump 3 of the fuel system 1 may be implemented by programmed instructions. These programmed instructions are typically constituted by a computer program, which, when it is executed in the control arrangement 21, ensures that the control arrangement 21 carries out the desired control, such as the method steps 110, 112, 120, 122, 124, 126, 128, 130, and 132 described herein. The computer program is usually part of a computer program product 200 which comprises a suitable digital storage medium on which the computer program is stored.

[0095] The control arrangement 21 may comprise a calculation unit which may take the form of substantially any suitable type of processor circuit or microcomputer, e.g. a circuit for digital signal processing (digital signal processor, DSP), a Central Processing Unit (CPU), a processing unit, a processing circuit, a processor, an Application Specific Integrated Circuit (ASIC), a microprocessor, or other processing logic that may interpret and execute instructions. The herein utilised expression "calculation unit" may represent a processing circuitry comprising a plurality of processing circuits, such as, e.g., any, some or all of the ones mentioned above.

[0096] The control arrangement 21 may further comprise a memory unit, wherein the calculation unit may be connected to the memory unit, which may provide the calculation unit with, for example, stored program code and/or stored data which the calculation unit may need to enable it to do calculations. The calculation unit may also be adapted to store partial or final results of calculations in the memory unit. The memory unit may comprise a physical device utilised to store data or programs, i.e., sequences of instructions, on a temporary or permanent basis. According to some embodiments, the memory unit may comprise integrated circuits comprising silicon-based transistors. The memory unit may comprise e.g. a memory card, a flash memory, a USB memory, a hard disc, or another similar volatile or non-volatile storage unit for storing data such as e.g. ROM (Read-Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable PROM), EEPROM (Electrically Erasable PROM), etc. in different embodiments.

[0097] The feature "obtaining", "obtain", "determining", and "determine", as referred to herein may comprise one or more calculations. As an alternative, or in addition, the feature "obtaining", "obtain", "determining", and "determine" as referred to herein may comprise retrieving data from one or more sensors, tables, matrices, or the like, or comparing obtained data with data from one or more tables, matrices, or the like. Therefore, throughout this disclosure, the wording "obtaining", "obtain", "determining", and "determine" may be replaced with the wording "calculate", "calculating", "retrieve" or "retrieving".

[0098] The control arrangement 21 is connected to components of the fuel system 1 and/or the vehicle 40 for receiving and/or sending input and output signals. These input and output signals may comprise waveforms, pulses, or other attributes which the input signal receiving devices can detect as information and which can be converted to signals processable by the control arrangement 21. These signals may then be supplied to the calculation unit. One or more output signal sending devices may be arranged to convert calculation results from the calculation unit to output signals for conveying to other parts of the vehicle's control system and/or the component or components for which the signals are intended. Each of the connections to the respective components of the fuel system 1 and/or the vehicle 40 for receiving and sending input and output signals may take the form of one or more from among a cable, a data bus, e.g. a CAN (controller area network) bus, a MOST (media orientated systems transport) bus or some other bus configuration, or a wireless connection.

[0099] In the embodiments illustrated, the fuel system 1 comprises a control arrangement 21 but might alternatively be implemented wholly or partly in two or more control arrangements or two or more control units.

[0100] Control systems in modern vehicles generally comprise a communication bus system consisting of one or more communication buses for connecting a number of electronic control units (ECUs), or controllers, to various components on board the vehicle. Such a control system may comprise a large number of control units and taking care of a specific function may be shared between two or more of them. Vehicles of the type here concerned are therefore often provided with significantly more control arrangements than depicted in Fig. 2, as one skilled in the art will surely appreciate.

[0101] The computer program product 200 may be provided for instance in the form of a data carrier carrying computer program code for performing at least some of the method steps 110, 112, 120, 122, 124, 126, 128, 130, and 132 according to some embodiments when being loaded into one or more calculation units of the control arrangement 21. The data carrier may be, e.g. a CD ROM disc, as is illustrated in Fig. 4, or a ROM (read-only memory), a PROM (programable read-only memory), an EPROM (erasable PROM), a flash memory, an EEPROM (electrically erasable PROM), a hard disc, a memory stick, an optical storage device, a magnetic storage device or any other appropriate medium such as a disk or tape that may hold machine readable data in a non-transitory manner. The computer program product may furthermore be provided as computer program code on a server and may be downloaded to the control arrangement 21 remotely, e.g., over an Internet or an intranet connection, or via other wired or wireless communication

systems.

[0102] The wording upstream and downstream, as used herein, relates to the relative positions of objects in relation to an intended flow direction of fluid in the system or conduit referred to. As an example, the feature that a first object arranged upstream of a second object in a conduit means that the first object is arranged before the second object seen relative to the intended flow direction of fluid through the conduit. As another example, the feature that a first object is arranged downstream of a second object in a conduit means that the first object is arranged after the second object seen relative to the intended flow direction of fluid through the conduit.

[0103] Since the data, as referred to herein, is representative of at least one of a flow and a pressure in the feed conduit 9, the data may also be referred to as flow and/or pressure data. The data representative of at least one of a flow and a pressure in the feed conduit 9 may be representative of a current flow and/or a current pressure in the feed conduit 9. Therefore, the data, as referred to herein, may also be referred to as current flow and/or pressure data. The flow in the feed conduit, as referred to herein, may encompass a flowrate of fuel in the feed conduit. Likewise, the flow in the feed conduit, as referred to herein, may encompass a current flowrate of fuel in the feed conduit. Therefore, the data, as referred to herein, may also be referred to as flowrate and/or pressure data or current flowrate and/or pressure data.

[0104] It is to be understood that the foregoing is illustrative of various example embodiments and that the invention is defined only by the appended independent claims. A person skilled in the art will realize that the example embodiments may be modified, and that different features of the example embodiments may be combined to create embodiments other than those described herein, without departing from the scope of the present invention, as defined by the appended independent claims.

[0105] As used herein, the term "comprising" or "comprises" is open-ended, and includes one or more stated features, elements, steps, components, or functions but does not preclude the presence or addition of one or more other features, elements, steps, components, functions, or groups thereof.

Claims

1. A method (100) of determining a condition of a fuel pump (3) of a fuel system (1) of a vehicle (40), the fuel system (1) comprising the fuel pump (3) and a feed pump (5) configured to feed fuel to the fuel pump (3) via a feed conduit (9), wherein the method (100) comprises the steps of:

   - operating (110) the feed pump (5) during stand still of the fuel pump (3),
   - obtaining (120) data representative of at least one of a flow and a pressure in the feed conduit (9), and
   - determining (130) a condition of the fuel pump (3) based on the data, **characterized in that** the fuel pump (3) comprises one or more fuel lubricated bearings (7), and **in that** the step of determining (130) a condition of the fuel pump (3) comprises the step of:
   - determining (132) a condition of the one or more fuel lubricated bearings (7).

2. The method (100), according to claim 1, wherein the step of operating (110) the feed pump (5) comprises the step of:

   - operating (112) the feed pump (5) to generate a constant feed pressure in the feed conduit (9),

   and wherein the step of obtaining (120) the data comprises the step of:

   - obtaining (122) data representative of a flow of fuel in the feed conduit (9).

3. The method (100) according to any one of the preceding claims, wherein the step/steps of obtaining (120, 122) the data comprises the step of:

   - obtaining (124) operational data of the feed pump (5).

4. The method (100) according to claim 3, wherein the feed pump (5) comprises an electric motor (15) configured to power the feed pump (5), and wherein the step of obtaining (124) the operational data of the feed pump (5) comprises the step of:

   - monitoring (126) electrical data of the electric motor (15).

5. The method (100) according to any one of the preceding claims, wherein the fuel system (1) comprises a pressure sensor (19) configured to sense a pressure in the feed conduit (9), and wherein the step of obtaining (120) the data comprises the step of:

   - obtaining (128) data from the pressure sensor (19).

6. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method (100) according to any one of the preceding claims.

7. A computer-readable medium (200) comprising instructions which, when executed by a computer, cause the computer to carry out the method (100) according to any one of the claims 1 - 5.

8. A control arrangement (21) configured to determine a condition of a fuel pump (3) of a fuel system (1) of a vehicle (40), wherein the fuel system (1) comprises the fuel pump (3), a feed pump (5), and a feed conduit (9), wherein the feed pump (5) is configured to feed fuel to the fuel pump (3) via the feed conduit (9), and wherein the control arrangement (21) is configured to:

- operate the feed pump (5) during stand still of the fuel pump (3),
- obtain data representative of at least one of a flow and a pressure in the feed conduit (9), and
- determine a condition of the fuel pump (3) based on the data,

characterized in that the fuel pump comprises one or more fuel lubricated bearings (7), and **in that** the step of determining (130) a condition of the fuel pump (3) comprises the step of:

- determining (132) a condition of the one or more fuel lubricated bearings (7) based on the data.

9. A fuel system (1) comprising a fuel pump (3), a feed pump (5), and a feed conduit (9), wherein the feed pump (5) is configured to feed fuel to the fuel pump (3) via the feed conduit (9), and wherein the fuel system (1) comprises a control arrangement (21) according to claim 8.

10. An internal combustion engine (10) comprising a fuel system (1) according to claim 9.

11. The internal combustion engine (10) according to claim 10, wherein the internal combustion engine (10) is a compression ignition engine.

12. A vehicle (40) comprising an internal combustion engine (10) according to claim 10 or claim 11.

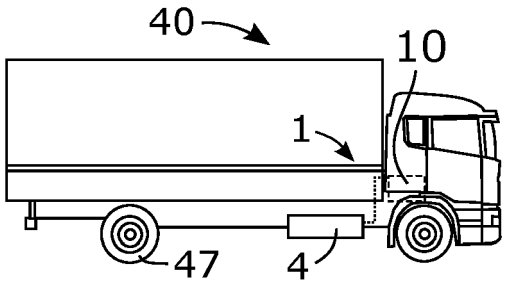

Fig. 1

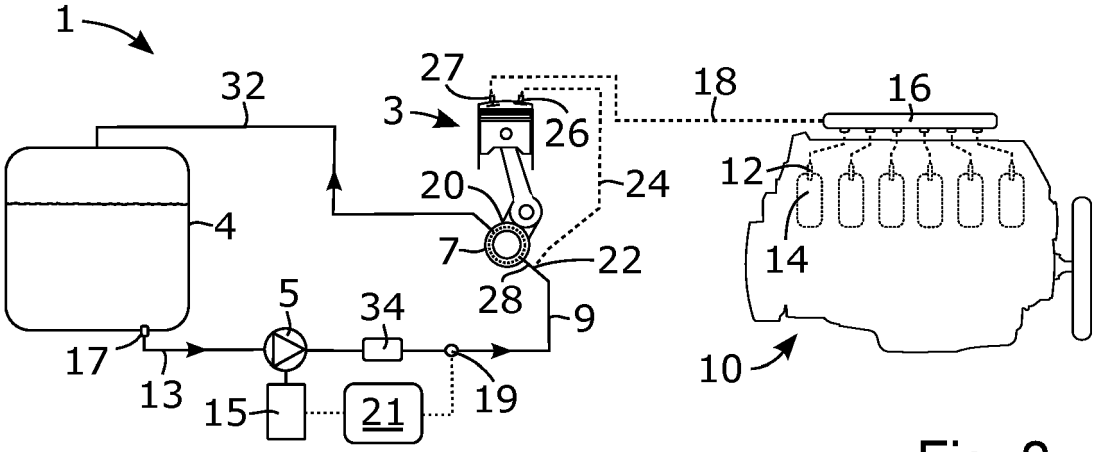

Fig. 2

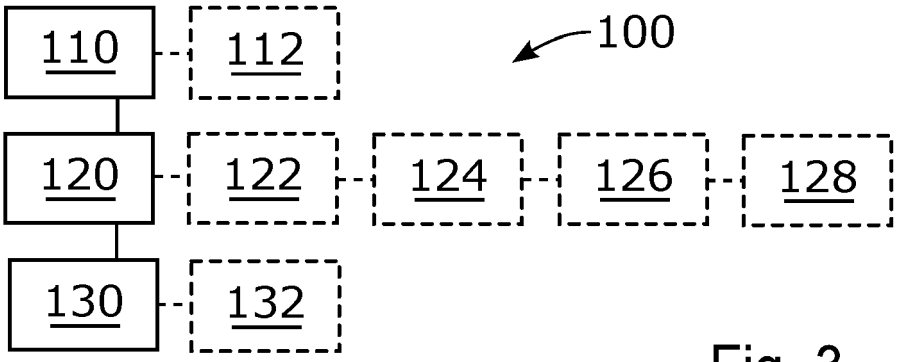

Fig. 3

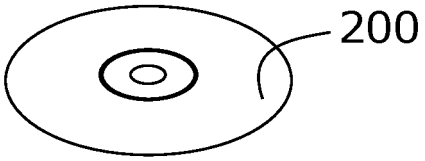

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 17 4768

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2016/153388 A1 (SANBORN ETHAN D [US] ET AL) 2 June 2016 (2016-06-02) * paragraphs [0021], [0026]; figures *	1-12	INV. F02D41/22 F02M37/08 F02M63/00
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TECHNICAL FIELDS SEARCHED (IPC)

F02D
F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	20 September 2022	Ulivieri, Enrico

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 17 4768

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
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20-09-2022

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