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

(11) EP 4 484 737 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.01.2025 Bulletin 2025/01

(21) Application number: **23182740.3**

(22) Date of filing: **30.06.2023**

(51) International Patent Classification (IPC):
F02D 41/00 *(2006.01)* ***F02D 41/02*** *(2006.01)*
F02D 41/14 *(2006.01)* ***F02D 41/08*** *(2006.01)*
F02D 9/08 *(2006.01)* ***F02D 13/02*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F02D 41/0255; F01N 3/10; F01N 3/2892; F01N 9/00; F01N 13/009; F02D 9/08; F02D 13/0215; F02D 41/0002; F02D 41/0245; F02D 41/08; F02D 41/1446; F01N 2240/20; F01N 2240/36; F02D 2041/001; F02D 2200/0802

(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: **Scania CV AB**
151 87 Södertälje (SE)

(72) Inventors:
- **LUNDBERG, Christer**
  144 64 Rönninge (SE)
- **SARBY, Håkan**
  141 42 Huddinge (SE)
- **DAHL, Andreas**
  611 44 Nyköping (SE)

(74) Representative: **Scania CV AB**
Patents, GP 117kv
151 87 Södertälje (SE)

(54) **METHOD OF OPERATING AN INTERNAL COMBUSTION ENGINE, CONTROL ARRANGEMENT, COMPUTER PROGRAM, COMPUTER-READABLE MEDIUM, AND ENGINE**

(57) A method (100) of operating an internal combustion engine (1). The method (100) comprises, during idling of the engine (1) operating (110) the engine (1) in a first mode of operation (m1) by controlling (111) a flow control assembly (6) to provide a nominal amount of gas pumped into an exhaust system (4) and controlling (112) an exhaust throttle (5) to the closed state, operating (120) the engine (1) in a second mode of operation (m2) by controlling (121) the flow control assembly (6) to provide a reduced amount of gas pumped into the exhaust system (4) and controlling (122) the exhaust throttle (5) to an open state, and switching (130) in an alternating manner between the first and second modes of operation (m1, m2). The present disclosure further relates to a control arrangement (21), a computer program, a computer-readable medium (200), an engine (1), and a vehicle (2).

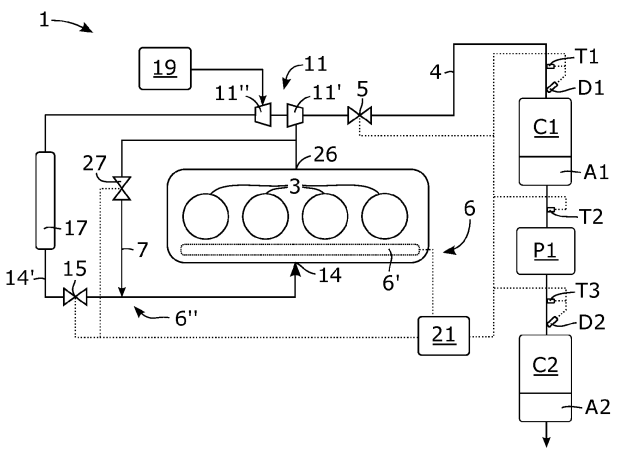

Fig. 2

EP 4 484 737 A1

Processed by Luminess, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method of operating an internal combustion engine. The present disclosure further relates to a control arrangement for an internal combustion engine, a computer program, a computer-readable medium, an engine, and a vehicle.

BACKGROUND

[0002] Internal combustion engines, such as four-stroke internal combustion engines, comprise one or more cylinders and a piston arranged in each cylinder. The pistons are connected to a crankshaft of the engine and are arranged to reciprocate within the cylinders upon rotation of the crankshaft. The engine usually further comprises one or more inlet valves and one or more outlet valves as well as one or more fuel supply arrangements. The one or more inlet valves and outlet valves are controlled by a respective valve control arrangement usually comprising one or more camshafts rotatably connected to a crankshaft of the engine, via a belt, chain, gears, or similar.

[0003] A four-stroke internal combustion engine completes four separate strokes while turning a crankshaft. A stroke refers to the full travel of the piston along the cylinder, in either direction. The uppermost position of the piston in the cylinder is usually referred to as the top dead centre TDC, and the lowermost position of the piston in the cylinder is usually referred to as the bottom dead centre BDC.

[0004] The strokes are completed in the following order, inlet stroke, compression stroke, expansion stroke and exhaust stroke. During operation of a conventional four-stroke internal combustion engine, the inlet valve control arrangement controls inlet valves of a cylinder to an open state during the inlet stroke of a piston within the cylinder, to allow air, or a mixture of air and fuel, to enter the cylinder. During the compression stroke, all valves should be closed to allow compression of the air, or the mixture of the air and fuel, in the cylinder. If the engine is in a power producing state, fuel in the cylinder is ignited, usually towards the end of the compression stroke, for example by a spark plug or by compression heat in the cylinder.

[0005] The combustion of fuel within the cylinder significantly increases pressure and temperature in the cylinder. The combustion of the fuel usually continues into a significant portion of the subsequent expansion stroke. The increased pressure and temperature in the cylinder obtained by the combustion is partially converted into mechanical work supplied to the crank shaft during the expansion stroke. Obviously, all valves should remain closed during the expansion stroke to allow the increased pressure and temperature to be converted into mechanical work. The expansion stroke is also usually referred to as the combustion stroke, since usually, most of the combustion takes place during the expansion stroke. In the subsequent exhaust stroke, the exhaust valve control arrangement controls exhaust valves of the cylinder to an open state to allow exhaust gases to be expelled out of the cylinder into an exhaust system of the combustion engine.

[0006] Some legislations require heavier vehicles to be provided with an auxiliary braking system in addition to wheel brakes. One type of auxiliary braking system is a so called exhaust brake which comprises an exhaust throttle arranged in the exhaust system of the engine. The exhaust throttle is controllable between an open state and a closed state, wherein the exhaust throttle restricts the flow of gas through the exhaust system to thereby generate a backpressure when controlled to the closed state. The backpressure opposes the upward motion of the pistons when they are moving toward the top dead centre in the exhaust stroke, which thereby increases the braking torque of the engine.

[0007] General problems when designing an internal combustion engine is the emission levels from the engine as well as the fuel consumption of the engine. The emission levels of carbon dioxide CO_2 are directly correlated to the fuel consumption of the engine. Moreover, exhausts from an engine can comprise carbon monoxide CO from incomplete combustion, hydrocarbons HC from unburnt fuel, nitrogen oxides NOx from high combustion temperatures, and particulate matter which is usually abbreviated PM and consists mostly of soot/smoke.

[0008] Nitrogen oxides NOx are formed by a reaction between oxygen 02 and nitrogen N upon high temperatures and pressures in a cylinder of an engine. In other words, when the operation of the engine is optimized regarding fuel efficiently, large amounts of nitrogen oxides NOx may be formed. Exhaust gas recirculation (EGR) is an effective strategy to control the NOx emissions from engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. The EGR reduces the formation of NOx through lowering the oxygen concentration in the combustion chamber, as well as through heat absorption, which reduces peak in-cylinder temperatures.

[0009] Due to environmental concerns, almost all vehicles for sale today comprise some sort of exhaust aftertreatment system. Examples are catalytic converters, particulate filters, and Selective catalytic reduction (SCR) arrangements. A selective catalytic reduction arrangement is a means of converting nitrogen oxides, also referred to as NOx with the aid of a catalyst into diatomic nitrogen N2, and water H2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia, or urea is added to a stream of exhaust gas and is adsorbed onto a catalytic substrate.

[0010] The conversion efficiency rate of these exhaust aftertreatment systems highly depends on the high temperature of the exhaust gases. Therefore, problems may arise in the converting efficiency of an exhaust aftertreatment system if the engine is operated to generate a low exhaust temperature, especially during cold starts, low engine load conditions, during engine idling, and similar operating conditions. Therefore, at certain times and/or conditions, it can be desired to operate the engine to increase the exhaust temperature even if it has a negative impact on the fuel consumption of the engine.

[0011] Engine idling refers to the operation of an internal combustion engine when it is running but not actively engaged in performing any useful work. During engine idling, the engine is operated to run at a low speed, typically around 600 to 1000 revolutions per minute (RPM), to maintain basic functions such as powering the vehicle's electrical systems, operating air conditioning or heating, and allowing for a quick restart when necessary.

[0012] Upcoming emission regulations require exhaust aftertreatment systems to be kept warm even during engine idling to be able to fulfil the maximum permitted NOx emission levels. One way to increase the temperature of an exhaust aftertreatment system is to inject more fuel. However, as a consequence, the engine speed will increase unless other measures are performed to restrict the engine speed, such as by controlling an exhaust throttle to a closed state. Increasing an injected fuel amount and closing an exhaust throttle is an efficient means of raising the temperature of an exhaust aftertreatment system to thereby maintain a conversion efficiency thereof. However, it will also cause a significant increase in fuel consumption.

[0013] For minimum fuel consumption, the exhaust flow to be heated should be minimized. However, if the exhaust flow is too small, the throttling of the exhaust gas by the exhaust throttle is not enough for keeping engine speed from rising at sufficient fuel quantity for the desired temperature. Moreover, if braked by other means, the engine would still have combustion stability issues at small exhaust flow and low fuel injection levels.

SUMMARY

[0014] It is an object of the present invention to overcome, or at least alleviate, at least some of the above-mentioned problems and drawbacks.

[0015] According to a first aspect of the invention, the object is achieved by a method of operating an internal combustion engine, wherein the method is performed by a control arrangement, and wherein the engine comprises a number of cylinders, a piston arranged in each cylinder to delimit a combustion chamber inside the cylinder, an exhaust system comprising one or more catalytic converters and an exhaust throttle controllable between an open state and a closed state, and a flow control assembly controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders into the exhaust system and a second state to provide a reduced amount of gas pumped from the number of cylinders into the exhaust system. The method comprises, during idling of the engine:

- operating the engine in a first mode of operation by controlling the flow control assembly to the first state and controlling the exhaust throttle to the closed state,
- operating the engine in a second mode of operation by controlling the flow control assembly to the second state and controlling the exhaust throttle to the open state, and
- switching in an alternating manner between the first and second modes of operation.

[0016] Since the method comprises the step of switching in an alternating manner between the first and second modes of operation, a method is provided having conditions for maintaining a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling of the engine.

[0017] This is because the method comprises the steps of controlling the flow control assembly to provide the nominal amount of gas pumped from the number of cylinders into the exhaust system and controlling the exhaust throttle to the closed state when operating the engine in the first mode of operation. Accordingly, the one or more catalytic converters will be heated in an efficient manner when the engine is operated in the first mode of operation. Therefore, the first mode of operation, as referred to herein, may also be referred to as a heating mode.

[0018] Moreover, as indicated above, the method comprises the steps of controlling the flow control assembly to provide the reduced amount of gas pumped from the number of cylinders into the exhaust system and controlling the exhaust throttle to the open state when operating the engine in the second mode of operation. The reduced amount of gas pumped from the number of cylinders into the exhaust system results in a low cooling rate of the one or more catalytic converters and the controlling of the exhaust throttle to the open state can ensure combustion stability despite a low flow of gas through the engine and a low fuel injection rate in the second mode of operation. Therefore, the second mode of operation, as referred to herein, may also be referred to as a temperature saving mode.

[0019] Accordingly, by switching in an alternating manner between the first and second modes of operation, a method is provided having conditions for maintaining a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling of the engine.

[0020] Since the temperature of the one or more catalytic converters can be maintained above a lower threshold temperature, the conversion efficiency rate thereof can be maintained while ensuring a low fuel consumption of the engine during idling. In other words, a method is provided having conditions for meeting upcoming emission legislations while minimizing the fuel consumption of the engine.

[0021] 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.

[0022] Optionally, the method comprises:

- providing a temperature estimate of at least one of the one or more catalytic converters, and
- switching from the first mode of operation to the second mode of operation when the temperature estimate rises above an upper threshold temperature.

[0023] Thereby, it can be ensured that a low cooling rate of the one or more catalytic converters is obtained when the temperature estimate rises above the upper threshold temperature and that the fuel consumption of the engine is minimized in such situations.

[0024] Optionally, the method comprises:

- providing a temperature estimate of at least one of the one or more catalytic converters, and
- switching from the second mode of operation to the first mode of operation when the temperature estimate declines below a lower threshold temperature.

[0025] Thereby, it can be ensured that the one or more catalytic converters is/are heated in an efficient manner when the temperature estimate declines below the lower threshold temperature. In other words, in this manner, it can be ensured that a high conversion efficiency rate of the one or more catalytic converters is maintained during engine idling of the engine.

[0026] Optionally, the method comprises:

- providing a temperature estimate of at least one of the one or more catalytic converters, and upon receipt of an idling request:
- selecting between initiating idling of the engine in the first mode of operation or in the second mode of operation based on the temperature estimate.

[0027] Thereby, a method is provided in which engine idling can be initiated in an optimal manner regarding fuel consumption and conversion efficiency rate of the one or more catalytic converters. This is because engine idling can be initiated in the first mode of operation if the temperature estimate is below a threshold temperature so as to efficiently heat the one or more catalytic converters and can be initiated in the second mode of operation if the temperature estimate is above a threshold temperature so as to efficiently maintain the temperature of the one or more catalytic converters.

[0028] Optionally, the step of providing the temperature estimate is performed using input from at least two different temperature sensors.

[0029] Thereby, a more robust and redundant switching can be performed between the first and second modes of operation. In other words, due to these features, further improved conditions are provided for maintaining a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling.

[0030] Optionally, the flow control assembly comprises a cam phaser arrangement controllable to regulate the amount of gas pumped from the number of cylinders into the exhaust system, and wherein the steps of controlling the flow control assembly to the first and second states are performed by:

- controlling the cam phaser arrangement to phase shift control of at least one of inlet valves and exhaust valves of the engine.

[0031] Thereby, the amount of gas pumped from the number of cylinders into the exhaust system can be controlled in an efficient manner.

[0032] Optionally, the step of controlling the flow control assembly to the second state comprises the steps of:

- advancing control of exhaust valves of the engine, and
- retarding control of inlet valves of the engine.

[0033] Thereby, the amount of gas pumped from the number of cylinders into the exhaust system can be controlled in an efficient manner while ensuring combustion stability and a low fuel consumption of the engine.

[0034] Optionally, the step of advancing the control of the exhaust valves comprises:

- advancing the control of the exhaust valves a number of crank angle degrees being within the range of 20 - 85, or within the range of 50 - 70.

[0035] Thereby, it can be ensured that a low amount of gas is pumped from the number of cylinders into the exhaust system so as to efficiently maintain a temperature of the one or more catalytic converters while ensuring combustion stability and a low fuel consumption of the engine.

[0036] Optionally, the step of retarding the control of the inlet valves comprises:

- retarding the control of the inlet valves a number of crank angle degrees being within the range of 20 - 85, or within the range of 45 - 60.

[0037] Thereby, it can be ensured that a low amount of gas is pumped from the number of cylinders into the exhaust system so as to efficiently maintain a temperature of the one or more catalytic converters while ensuring combustion stability and a low fuel consumption of the engine.

[0038] Optionally, the engine comprises an exhaust gas recirculation loop configured to recirculate exhaust gas from an exhaust outlet of the engine to an air inlet of the engine, and wherein the flow control assembly comprises a throttle controllable to regulate the amount of exhaust gas flowing to the exhaust gas recirculation loop, and wherein the steps of controlling the flow control assembly between the first and second states is performed by:

- controlling an opening degree of the throttle.

[0039] Thereby, the amount of gas pumped from the number of cylinders into the exhaust system can be controlled in a simple and efficient manner.

[0040] According to a second aspect of the invention, the object is achieved by a control arrangement for an internal combustion engine, and wherein the engine comprises a number of cylinders, a piston arranged in each cylinder to delimit a combustion chamber inside the cylinder, an exhaust system comprising one or more catalytic converters and an exhaust throttle controllable between an open state and a closed state, and a flow control assembly controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders into the exhaust system and a second state to provide a reduced amount of gas pumped from the number of cylinders into the exhaust system. The control arrangement is configured to, during idling of the engine:

- operate the engine in a first mode of operation by controlling the flow control assembly to the first state and controlling the exhaust throttle to the closed state,
- operate the engine in a second mode of operation by controlling the flow control assembly to the second state and controlling the exhaust throttle to the open state, and
- switch in an alternating manner between the first and second modes of operation.

[0041] Since the control arrangement is configured to switch in an alternating manner between the first and second modes of operation, a control arrangement is provided having conditions for maintaining a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling of the engine.

[0042] This is because the control arrangement is configured to control the flow control assembly to provide the nominal amount of gas pumped from the number of cylinders into the exhaust system and control the exhaust throttle to the closed state when operating the engine in the first mode of operation. Accordingly, the one or more catalytic converters will be heated in an efficient manner when the engine is operated in the first mode of operation by the control arrangement. Therefore, the first mode of operation, as referred to herein, may also be referred to as a heating mode.

[0043] Moreover, as indicated above, the control arrangement is configured to control the flow control assembly to provide the reduced amount of gas pumped from the number of cylinders into the exhaust system and control the exhaust throttle to the open state when operating the engine in the second mode of operation. The reduced amount of gas pumped from the number of cylinders into the exhaust system results in a low cooling rate of the one or more catalytic converters and the control of the exhaust throttle to the open state can ensure combustion stability despite a low flow of gas through the engine and a low fuel injection rate in the second mode of operation. Therefore, the second mode of operation, as referred to herein, may also be referred to as a temperature saving mode.

[0044] Accordingly, by switching in an alternating manner between the first and second modes of operation, the control performed by the control arrangement can maintain a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling.

[0045] Since the temperature of the one or more catalytic converters can be maintained above a lower threshold temperature, the conversion efficiency rate thereof can be maintained while ensuring a low fuel consumption of the engine during idling. In other words, a control arrangement is provided having conditions for meeting upcoming emission legislations while minimizing the fuel consumption of the engine.

[0046] 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.

[0047] According to a third aspect of the invention, the object is achieved by a computer program comprising instructions to cause the control arrangement according to the second aspect of the invention to execute the steps of the method according to some embodiments of the first aspect of the invention. Since the computer program comprises instructions to cause the control arrangement to carry out the method according to some embodiments described herein, 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.

[0048] According to a fourth aspect of the invention, the object is achieved by a computer-readable medium having stored thereon the computer program according to the third aspect of the invention. Since the computer-readable medium comprises instructions to cause the control arrangement to carry out the method according to some embodiments described herein, 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.

[0049] According to a fifth aspect of the invention, the object is achieved by an engine comprising a number of cylinders, a piston arranged in each cylinder to delimit a combustion chamber inside the cylinder, an exhaust system comprising one or more catalytic converters and an exhaust throttle controllable between an open state and a closed state, and a flow control assembly controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders into the exhaust system and a second state to provide a reduced amount of gas pumped from the number of cylinders into the exhaust system, and a control arrangement configured to, during idling of the engine:

- operate the engine in a first mode of operation by controlling the flow control assembly to the first state and controlling the exhaust throttle to the closed state,
- operate the engine in a second mode of operation by controlling the flow control assembly to the second state and controlling the exhaust throttle to the open state, and
- switch in an alternating manner between the first and second modes of operation.

[0050] Since the control arrangement of the engine is configured to switch in an alternating manner between the first and second modes of operation, an engine is provided having conditions for maintaining a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption during idling.

[0051] This is because the control arrangement of the engine is configured to control the flow control assembly to provide the nominal amount of gas pumped from the number of cylinders into the exhaust system and control the exhaust throttle to the closed state when operating the engine in the first mode of operation. Accordingly, the one or more catalytic converters will be heated in an efficient manner when the engine is operated in the first mode of operation by the control arrangement of the engine.

[0052] Moreover, as indicated above, the control arrangement of the engine is configured to control the flow control assembly to provide the reduced amount of gas pumped from the number of cylinders into the exhaust system and control the exhaust throttle to the open state when operating the engine in the second mode of operation. The reduced amount of gas pumped from the number of cylinders into the exhaust system results in a low cooling rate of the one or more catalytic converters and the control of the exhaust throttle to the open state can ensure combustion stability despite a low flow of gas through the engine and a low fuel injection rate in the second mode of operation.

[0053] Accordingly, by switching in an alternating manner between the first and second modes of operation, the control performed by the control arrangement of the engine can maintain a temperature of the one or more catalytic converters above a lower threshold temperature while minimizing the fuel consumption of the engine during idling.

[0054] Since the temperature of the one or more catalytic converters can be maintained above a lower threshold temperature, the conversion efficiency rate thereof can be maintained while ensuring a low fuel consumption of the engine during idling. In other words, a control arrangement is provided having conditions for meeting upcoming emission legislations while minimizing the fuel consumption of the engine.

[0055] Accordingly, an 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.

[0056] According to a sixth aspect of the invention, the object is achieved by a vehicle comprising an engine according to the fifth aspect of the invention. Since the vehicle comprises an engine according to the fifth aspect of the invention, 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.

[0057] 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

[0058] 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 schematically illustrates a vehicle according to some embodiments,
Fig. 2 schematically illustrates an internal combustion engine of the vehicle illustrated in Fig. 1,
Fig. 3 schematically illustrates a cross sectional view of the internal combustion engine illustrated in Fig. 2,
Fig. 4a and Fig. 4b illustrate valve lift events in different operational states of a cam phaser arrangement of the engine illustrated in Fig. 2 and Fig. 3,
Fig. 5 illustrates an upper graph showing temperature data as a function of time from a first, a second, and a third temperature sensor of the engine illustrated in Fig. 2 and Fig. 3, and a lower graph showing a current operational mode of the engine illustrated in Fig. 2 and Fig. 3,
Fig. 6 schematically illustrates a method of operating an internal combustion engine, and
Fig. 7 illustrates a computer-readable medium.

DETAILED DESCRIPTION

[0059] Aspects of the present invention will now be described more fully. Like reference signs refer to like elements throughout. Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity.

[0060] Fig. 1 schematically illustrates a vehicle 2 according to some embodiments of the present disclosure. According to the illustrated embodiments, the vehicle 2 is a truck, i.e. a type of heavy road vehicle, as well as a type of heavy commercial vehicle. According to further embodiments, the vehicle 2, as referred to herein, may be another type of heavy or lighter type of manned or unmanned vehicle for land based propulsion such as a lorry, a bus, a construction vehicle, a tractor, a car, or the like.

[0061] The vehicle 2 comprises an internal combustion engine 1. According to the illustrated embodiments, the internal combustion engine 1 is configured to provide motive power to the vehicle 2 via wheels 47 of the vehicle 2. The vehicle 2 may comprise one or more electric propulsion motors in addition to the internal combustion engine 1 for providing motive power to the vehicle 2. Thus, the vehicle 2 may comprise a so called hybrid electric powertrain comprising one or more electric propulsion motors in addition to the internal combustion engine 1 for providing motive power to the vehicle 2.

[0062] For reasons of brevity and clarity, the internal combustion engine 1 is in some places herein simply referred to as "the engine 1".

[0063] Fig. 2 schematically illustrates the internal combustion engine 1 of the vehicle 2 illustrated in Fig. 1. Cylinders 3 of the engine 1 are schematically indicated in Fig. 2. According to the illustrated embodiments, the engine 1 comprises four cylinders 3 arranged in one row. The engine 1 according to the illustrated embodiments may therefore be referred to an inline-four engine. However, according to further embodiments, the engine 1, as referred to herein, may comprise another number of cylinders 3. Moreover, the cylinders 3 of the engine 1 may be arranged in another configuration than in one row, such as in two or more rows.

[0064] According to the illustrated embodiments, the internal combustion engine 1 is a diesel engine, i.e. a type of compression ignition engine. The internal combustion engine 1 may thus be configured to operate on diesel or a diesel-like fuel, such as biodiesel, biomass to liquid (BTL), or gas to liquid (GTL) diesel. 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).

[0065] According to further embodiments, the internal combustion engine 1, as referred to herein, 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. Alcohol, such as ethanol, can be derived from renewable biomass. According to embodiments herein, the internal combustion engine 1 is a four-stroke internal combustion engine 1.

[0066] The engine 1 comprises an air inlet 14 and an exhaust outlet 26. The engine 1 further comprises an air inlet duct 14' connected to the air inlet 14 and an exhaust system 4 connected to exhaust outlet 26 of the engine 1. The exhaust system 4 is configured to conduct exhaust gas from the exhaust outlet 26 to the surroundings.

[0067] According to the illustrated embodiments, the engine 1 further comprises a turbocharger 11. The turbocharger 11 comprises a turbine 11' driven by exhaust gas flowing out from the engine 1 via the exhaust outlet 26. Moreover, the turbocharger 11 comprises a compressor wheel 11" connected to the turbine 11'. The compressor wheel 11" is configured to compress air from an air filter assembly 19 of the engine 1 to the air inlet 14 of the engine 1. The compressor wheel 11" may be connected to the turbine 11' via a shaft. Moreover, according to the illustrated embodiments, the engine 1 comprises a charge air cooler 17. The charge air cooler 17 is configured to cool the air compressed by the compressor wheel 11" before the air is conducted to the air inlet 14 of the engine 1.

[0068] According to further embodiments, the engine 1 may lack a turbocharger and/or may comprise one or more other types of supercharger devices, such as one or more compressors. Moreover, according to some embodiments, the engine 1 may comprise two or more turbochargers, wherein the two or more turbochargers may be arranged in parallel or on series.

[0069] According to the illustrated embodiments, the exhaust system 4 comprises two catalytic converters C1, C2 and a diesel particulate filter P1. According to further embodiments, the exhaust system 4 may comprise another number of catalytic converters, such as one, three, four, or the like.

[0070] In more detail, according to the illustrated embodiments, the exhaust system 4 comprises a first Selective Catalytic Reduction (SCR) catalyst C1 and a second Selective Catalytic Reduction (SCR) catalyst C2, wherein the second Selective Catalytic Reduction (SCR) catalyst C2 is arranged downstream of the first Selective Catalytic Reduction (SCR) catalyst C1 in the exhaust system 4. Moreover, according to the illustrated embodiments, each of the first and second Selective Catalytic Reduction (SCR) catalysts C1, C2 comprises a respective ammonia slip catalyst A1, A2. According to the illustrated embodiments, the diesel particulate filter P1 is positioned between the first and second Selective Catalytic Reduction (SCR) catalysts C1, C2.

[0071] The exhaust system 4 further comprises a first reductant dosing unit D1 and a second reductant dosing unit D2. The first reductant dosing unit D1 is arranged upstream of a catalytic substrate of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second reductant dosing unit D2 is arranged upstream of a catalytic substrate of the second a Selective Catalytic Reduction (SCR) catalyst C2. Each of the first and second reductant dosing units D1, D2 is configured to introduce a reductant, such as an aqueous solution of urea known as Diesel Exhaust Fluid (DEF), into the exhaust stream. When the exhaust gases pass through a catalytic substrate of the respective SCR catalyst C1, C2, the urea reacts with the NOx, converting it into nitrogen (N2) and water (H2O).

[0072] In some cases, a small amount of unreacted ammonia, known as "ammonia slip," may escape a SCR catalyst C1, C2 without undergoing the desired reaction. To address this issue, the ammonia slip catalysts A1, A2 are added downstream of the respective SCR catalyst C1, C2. The ammonia slip catalysts A1, A2 are designed to promote a secondary reaction, where the remaining ammonia in the exhaust gas is further oxidized and converted into nitrogen and water vapor. By incorporating the ammonia slip catalysts A1, A2, the overall efficiency of the SCR system is improved, ensuring that a minimal amount of ammonia is emitted into the environment.

[0073] An ammonia slip catalyst A1, A2 typically comprises a high-surface-area catalyst that facilitates the oxidation of ammonia. It operates under specific temperature and operating conditions to ensure optimal performance. The presence of the ammonia slip catalysts A1, A2 helps to meet strict emission standards and ensures that the SCR system operates efficiently, minimizing both nitrogen oxide (NOx) and ammonia (NH3) emissions.

[0074] The exhaust system 4 further comprises a first temperature sensor T1, a second temperature sensor T2, and a third temperature sensor T3. The first temperature sensor T1 is configured to provide data representative of the temperature of exhaust gas flowing into the first Selective Catalytic Reduction (SCR) catalyst C1. The second temperature sensor T2 is configured to provide data representative of the temperature of exhaust gas flowing into the diesel particulate filter P1. The third temperature sensor T3 is configured to provide data representative of the temperature of exhaust gas flowing into the second Selective Catalytic Reduction (SCR) catalyst C2. According to the illustrated embodiments, the first temperature sensor T1 is positioned at a gas inlet of the first Selective Catalytic Reduction (SCR) catalyst C1, the second temperature sensor T2 is positioned at a gas inlet of the diesel particulate filter P1, and the third temperature sensor T3 is positioned at a gas inlet of the second Selective Catalytic Reduction (SCR) catalyst C2. According to further embodiments, the exhaust system 4 may comprise another number of temperature sensors which may be positioned in another manner than described above, and in another manner than what is depicted in Fig. 2.

[0075] The exhaust system 4 further comprises an exhaust throttle 5. The exhaust throttle 5 is controllable between an open state and a closed state. The exhaust throttle 5 is configured to provide at least substantially no restriction of exhaust flow through the exhaust throttle 5 when the exhaust throttle 5 is in the open state. The exhaust throttle 5 is configured to provide a restriction of the flow of exhaust gas through the exhaust throttle 5 when the exhaust throttle 5 is in the closed state. The closed state of the exhaust throttle 5, as referred to herein, may also be referred to as an at least partially closed state, a partially closed state, or the like.

[0076] The exhaust throttle 5 may for example be controlled to the closed state when wanting to provide additional braking force onto a vehicle 2 comprising the engine 1. The additional braking force is provided due to an increased force on pistons of the engine 1 for pumping gas out from the cylinders 3 in exhaust strokes of the cylinders 3 when the exhaust throttle 5 is in the closed state. According to the illustrated embodiments, the exhaust throttle 5 is positioned between the turbine 11' of the turbocharger 11 and the first Selective Catalytic Reduction (SCR) catalyst C1.

[0077] The engine 1 further comprises a flow control assembly 6. The flow control assembly 6 is controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders 3 into the exhaust system 4 and a second state to provide a reduced amount of gas pumped from the number of cylinders 3 into the exhaust system 4. The features, functions, and advantages of the flow control assembly 6 are explained in more detail below.

[0078] Moreover, as indicated in Fig. 2, the engine 1 comprises a control arrangement 21. According to the illustrated embodiments, the control arrangement 21 is operably connected to the flow control assembly 6, the exhaust throttle 5, the first temperature sensor T1, the first reductant dosing unit D1, the second temperature sensor T2, the third temperature sensor T3, and the second reductant dosing unit D2.

[0079] Fig. 3 schematically illustrates a cross sectional view of the internal combustion engine 1 illustrated in Fig. 2. In Fig. 3, the cross section is made in a plane comprising a centre axis of one of the cylinders 3 of the engine 1. The engine 1 comprises at least one cylinder 3 and a piston 12 arranged in each cylinder 3. The piston 12 delimits a combustion chamber 3' inside the cylinder 3 and is connected via a connecting rod 13 to a crankshaft 16, which at rotation moves the piston 12 forwards and backwards in the cylinder 3, between a top dead centre (TDC) and a bottom dead centre (BDC). In Fig. 3, the piston 12 is illustrated in a region of the top dead centre.

[0080] Moreover, in Fig. 3, the air inlet 14 and the exhaust outlet 26 of the engine 1 are indicated. The engine 1 further comprises at least one inlet valve 18 arranged in each cylinder 3, which at least one inlet valve 18 is connected with the air inlet 14. The engine 1 further comprises an inlet valve control arrangement 22 configured to control each inlet valve 18 on the basis of a rotational position of the crankshaft 16. The engine 1 further comprises at least one exhaust valve 24 arranged in each cylinder 3, which at least one exhaust valve 24 is connected with an exhaust outlet 26 of the engine 1.

[0081] The engine 1 further comprises an exhaust valve control arrangement 28 configured to control each exhaust valve 24 on the basis of the rotational position of the crankshaft 16. In Fig. 3, the inlet valve 18 and the exhaust valve 24 are illustrated in a respective fully closed position. In a fully closed position, each valve 18, 24 abuts against a respective valve seat to close fluid connection between the cylinder 3 and the respective air inlet 14 and the exhaust outlet 26.

[0082] The inlet valve control arrangement 22 is arranged to control the at least one inlet valve 18 between the fully closed position and an open position by displacing the at least one inlet valve 18 in a direction into the cylinder 3. A fluid connection is thereby opened between the air inlet 14 and the cylinder 3. Likewise, the exhaust valve control arrangement 28 is arranged to control the at least one exhaust valve 24 between the fully closed position to an open position by displacing the at least one exhaust valve 24 in a direction into the cylinder 3. Thereby, a fluid connection is opened between the cylinder 3 and the exhaust outlet 26. Upon displacement of a valve 18, 24 from the closed position to the open position, the valve 18, 24 is lifted from its valve seat.

[0083] According to the illustrated embodiments, the engine comprises one fuel injector i1 per cylinder 3 wherein each fuel injector i1 is configured to inject fuel directly into a cylinder 3 of the internal combustion engine 1. According to further embodiments, the internal combustion engine 1 may comprise another number of fuel injectors i1 per cylinder 3. Moreover, according to some embodiments, the internal combustion engine 1 may comprise one or more fuel injectors configured to inject fuel into an air inlet of the combustion engine 1 as an alternative to fuel injectors i1 configured to inject fuel into the cylinders 3 or in addition to the fuel injectors i1 configured to inject fuel into the cylinders 3. According to the illustrated embodiments, the control arrangement 21 of the engine 1 is operably connected to each fuel injector i1 and is configured to control the operation thereof.

[0084] The exhaust valve control arrangement 28 and the inlet valve control arrangement 22 may each comprise one or more camshafts 71, 72 rotatably connected to the crankshaft 16 of the engine 1. Moreover, the exhaust valve control arrangement 28 and the inlet valve control arrangement 22 may each comprise one or more arrangements, such as rocker arms 73, 74, for transferring movement of cam lobes of the camshafts 71, 72 to valve stems of the valves 18, 24 to open and close the valves 18, 24 upon rotation of the respective camshaft 71, 72.

[0085] According to further embodiments, the cam lobes of the camshafts 71, 72 of the engine 1 may be arranged to displace valves 18, 24 to an open position by pressing onto valve stems of the valves 18, 24 upon rotation of the respective camshaft 71, 72. The exhaust valve control arrangement 28 and/or the inlet valve control arrangement 22 may according to further embodiments comprise electric, pneumatic, or hydraulic actuators arranged to control valves based on the rotational position of the crankshaft 16. The rotational position of the crankshaft 16 may be obtained using a crank angle sensor 29.

[0086] In the following, some features, functions, and advantages of the flow control assembly 6 are further explained with simultaneous reference to Fig. 1 - Fig. 3. As mentioned, the flow control assembly 6 is controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders 3 into the exhaust system 4 and a second state to provide a reduced amount of gas pumped from the number of cylinders 3 into the exhaust system 4.

[0087] As indicated in Fig. 2, according to the illustrated embodiments, the flow control assembly 6 comprises an Exhaust Gas Recirculation (EGR) system 6". The Exhaust Gas Recirculation (EGR) system 6" comprises an exhaust gas recirculation loop 7 configured to recirculate exhaust gas from an exhaust outlet 26 of the engine 1 to an air inlet 14 of the engine 1. Moreover, the Exhaust Gas Recirculation (EGR) system 6" of the flow control assembly 6 comprises a throttle 27 controllable to regulate the amount of exhaust gas flowing to the exhaust gas recirculation loop 7. According to the illustrated embodiments, the throttle 27 is an EGR-throttle arranged in the exhaust gas recirculation loop 7.

[0088] As seen in Fig. 2, according to the illustrated embodiments, the control arrangement 21 is operably connected to the throttle 27 and is configured to control an opening degree of the throttle 27 so as to regulate the amount of gas pumped from the number of cylinders 3 into the exhaust system 4. According to the illustrated embodiments, the control arrangement 21 is configured to decrease an opening degree of the throttle 27 upon switching to a first state and is configured to increase the opening degree of the throttle 27 upon switching to a second state.

[0089] If the throttle 27 is controlled towards a more open state, i.e., if the opening degree of the throttle 27 is increased, more gas will be conducted through the exhaust gas recirculation loop 7 and consequently less gas will be pumped from the number of cylinders 3 into the exhaust system 4. Moreover, if the throttle 27 is controlled towards a more closed state, i.e., if the opening degree of the throttle 27 is decreased, less gas will be conducted through the exhaust gas recirculation loop 7 and more gas will be pumped from the number of cylinders 3 into the exhaust system 4. In other words, a higher proportion of gas flowing through the exhaust gas recirculation loop 7 leads to a reduced amount of gas pumped from the number of cylinders 3 into the exhaust system 4 and vice versa. These and further aspects of the control performed by the control arrangement 21 are explained in greater detail below.

[0090] Moreover, according to the illustrated embodiments, the flow control assembly 6 comprises an air inlet throttle 15 arranged in the air inlet duct 14' of the engine 1. As seen in Fig. 2, according to the illustrated embodiments, the control arrangement 21 is operably connected to the air inlet throttle 15 and is configured to control an opening degree of the air inlet throttle 15 so as to regulate the amount of gas pumped from the number of cylinders 3 into the exhaust system 4. According to the illustrated embodiments, the control arrangement 21 is configured to increase an opening degree of the air inlet throttle 15 upon switching to the first state and is configured to decrease the opening degree of the air inlet throttle 15 upon switching to the second state.

[0091] If the air inlet throttle 15 is controlled towards a more closed state, i.e., if the opening degree of the air inlet throttle 15 is decreased, more gas will be conducted through the exhaust gas recirculation loop 7 and consequently less gas will be pumped from the number of cylinders 3 into the exhaust system 4. Moreover, if the air inlet throttle 15 is controlled towards a more open state, i.e., if the opening degree of the air inlet throttle 15 is increased, less gas will be conducted through the exhaust gas recirculation loop 7 and more gas will be pumped from the number of cylinders 3 into the exhaust system 4. In other words, a higher proportion of gas flowing through the exhaust gas recirculation loop 7 leads to a reduced amount of gas pumped from the number of cylinders 3 into the exhaust system 4 and vice versa. These and further aspects of the control performed by the control arrangement 21 are explained in greater detail below.

[0092] The exhaust gas recirculation loop 7 may as an alternative, or in addition, comprise one or more other types of throttles controllable by the control arrangement 21 so as to regulate the amount of gas pumped from the number of cylinders 3 into the exhaust system 4. Moreover, the exhaust gas recirculation loop 7 may comprise one or more further arrangements or systems, such as an EGR cooler.

[0093] Furthermore, as is indicated in Fig. 2, according to the illustrated embodiments, the flow control assembly 6 comprises a cam phaser arrangement 6'. As is explained in the following, the cam phaser arrangement 6' is controllable to regulate the amount of gas pumped from the number of cylinders 3 into the exhaust system 4. According to the illustrated embodiments, the flow control assembly 6 of the engine 1 comprises the Exhaust Gas Recirculation (EGR) system 6" as well as the cam phaser arrangement 6'. According to further embodiments, the flow control assembly 6 of the engine 1 may comprise only one of the Exhaust Gas Recirculation (EGR) system 6" and the cam phaser arrangement 6' for regulating the amount of gas pumped from the number of cylinders 3 into the exhaust system 4.

[0094] The cam phaser arrangement 6' of the flow control assembly 6 is also indicated in Fig. 3. According to the illustrated embodiments, the cam phaser arrangement 6' comprises an exhaust valve phase-shifting device 30 configured to phase-shift control of the at least one exhaust valve 24 in relation to the crankshaft 16. Moreover, according to the illustrated embodiments, the cam phaser arrangement 6' comprises an inlet valve phase-shifting device 32 configured to phase-shift control of the at least one inlet valve 18 in relation to the crankshaft 16.

[0095] The exhaust valve phase-shifting device 30 and the inlet valve phase-shifting device 32 may each comprise a hydraulic arrangement, for example using engine oil as hydraulic fluid, to phase-shift control of the valves 18, 24 in relation to the crankshaft 16. Such hydraulic arrangement may form part of a belt pulley, gear wheel, sprocket, or the like (not illustrated) arranged to transfer rotation from the crankshaft 16 to a camshaft 71, 72 of the exhaust valve control arrangement 28 and/or the inlet valve control arrangement 22. The hydraulic arrangement may be arranged to regulate an angular relationship between a first portion of the belt pulley, gear wheel, sprocket, or the like, being connected to the crankshaft 16, and a second portion of the belt pulley, gear wheel, sprocket, or the like, being connected to the camshaft 71, 72, in order to phase-shift control of the at least one inlet valve 18 and/or the at least one exhaust valve 24. In embodiments wherein the exhaust valve control arrangement 28 and/or the inlet valve control arrangement 22 comprises electric, pneumatic, or hydraulic actuators, the phase-shift of control of the at least one inlet valve 18 and/or the at least one exhaust valve 24 may be performed in another manner, for example by an electronic phase-shift of control.

[0096] According to the illustrated embodiments, the control arrangement 21 of the engine 1 is operably connected to each of the exhaust valve phase-shifting device 30 and the inlet valve phase-shifting device 32 and is configured to control operation thereof. The control arrangement 21 may be operably connected to one or more further components and systems of the engine 1, such as the inlet valve control arrangement 22 and the exhaust valve control arrangement 28 and may be configured to control operation thereof. Furthermore, the control arrangement 21 may be connected to a number of different sensors to obtain signals therefrom. Examples are sensors arranged to sense exhaust pressure, charge air temperature, mass airflow, throttle position, engine speed, engine load, absolute pressure in an inlet manifold, rotational position of the crank shaft 16, and the like.

[0097] **Fig. 4a and Fig. 4b** illustrate valve lift events 51, 52 in different operational states of the cam phaser arrangement 6' of the engine 1 illustrated in Fig. 2 and Fig. 3. Therefore, below, reference is made to the Fig. 1 - Fig. 4b, if not indicated otherwise. The curves illustrated in Fig. 4a and Fig. 4b illustrate valve lift events performed during two revolutions of the crank shaft 16, i.e. during all four strokes of the four-stroke internal combustion engine 1. In these figures, the strokes are illustrated in the following order: compression stroke 41, expansion stroke 42, exhaust stroke 43 and inlet stroke 44.

[0098] Fig. 4a illustrates valve lift events 51 of the at least one inlet valve 18, and valve lift events 52 of the at least one exhaust valve 24, obtained when the cam phaser arrangement 6' is in a first state. As indicated, during the compression stroke 41 and the expansion stroke 42, the at least one inlet valve 18 and the at least one exhaust valve 24 are closed. When the piston reaches the bottom dead centre BDC at the end of the expansion stroke 42, the exhaust valve control arrangement 28 controls the at least one exhaust valve 24 to an open position to allow exhaust gases to be expelled from the cylinder 3 to the exhaust outlet 26 during the exhaust stroke 43. In the transition area between the exhaust stroke 43 and the inlet stroke 44, the exhaust valve control arrangement 28 controls the at least one exhaust valve 24 to a closed position.

[0099] Moreover, in the transition area between the exhaust stroke 43 and the inlet stroke 44, the inlet valve control arrangement 22 controls the at least one inlet valve 18 to an open position to allow air, or an air/fuel mixture, to enter the cylinder 3 during the inlet stroke 44. Towards the end of the inlet stroke 44, the inlet valve control arrangement 22 controls the at least one inlet valve 18 to a closed position to allow compression of the air, or the air/fuel mixture, in the subsequent compression stroke 41. The valve lift events 51 of the at least one inlet valve 18 and the valve lift events 52 of the at least one exhaust valve 24 illustrated in Fig. 4a may be the same during normal engine braking of the engine 1, occurring for example when a driver of a vehicle releases an accelerator pedal. A nominal amount of gas pumped from the number of cylinders 3 into the exhaust system 4 is provided when the cam phaser arrangement 6' is in the first state.

[0100] The nominal amount of gas pumped from the number of cylinders 3 into the exhaust system 4 may also be referred to as a standard amount of gas for example obtained when a cam phaser arrangement 6' of the engine 1 provides nominal control of phase shifting of the at least one inlet valve 18 and of the at least one exhaust valve 24, as illustrated in Fig. 4a, and/or when an Exhaust Gas Recirculation (EGR) system 6" of the engine 1 is controlled to provide a nominal flow of exhaust gas through an exhaust gas recirculation loop 7 of the engine 1.

[0101] **Fig. 4b** illustrates valve lift events 51 of the at least one inlet valve 18 and valve lift events 52 of the at least one exhaust valve 24, obtained when the cam phaser arrangement 6' is in a second state. As seen in Fig. 4b, the cam phaser arrangement 6' has phase shifted control of the inlet valves 18 and the exhaust valves 24 of the engine 1 when transitioning from the first state to the second state.

[0102] In more detail, the cam phaser arrangement 6' has phase shifted control of at least one exhaust valve 24 of the cylinder 3 such that opening and closing events 62, 62' of the at least one exhaust valve 24 are advanced as compared to when operating in the first state illustrated in Fig. 4a. That is, as can be seen when comparing Fig. 4a and Fig. 4b, the control of the at least one exhaust valve 24 has been phase shifted such that an opening event 62 of the at least one exhaust valve 24 is obtained in the expansion stroke 42 of the cylinder 3 and such that a closing event 62' of the at least one exhaust valve 24 is obtained in the exhaust stroke 43 of the cylinder 3.

[0103] In Fig. 4b, the control of the at least one exhaust valve 24 has been advanced approximately 60 crank angle degrees as compared to when cam phaser arrangement 6' is operating in the first state, i.e. as illustrated in Fig. 4a. According to some embodiments, the cam phaser arrangement 6' may phase shift control of the exhaust valves 24 a number of crank angle degrees being within the range of 20 - 85, or within the range of 50 - 70 upon transitioning from the first state to the second state. By advancing control of at least one exhaust valve 24, less gas is pumped out of the cylinder 3 to the exhaust outlet 26 and consequently also to the exhaust system 4 of the engine 1.

[0104] Moreover, as can be seen in Fig. 4b, according to the illustrated embodiments, the cam phaser arrangement 6' has retarded control of the inlet valves 18 of the engine 1 upon transitioning from the first state illustrated in Fig. 4a to the second state illustrated in Fig. 4b. In more detail, the cam phaser arrangement 6' has phase shifted control of the at least one inlet valve 18 of the cylinder 3 such that an opening event 61 of the at least one inlet valve 18 is obtained in the intake stroke 44 and a closing event 61' of the at least one inlet valve 18 is obtained in the compression stroke 41 of the engine 1.

[0105] According to the illustrated embodiments, the cam phaser arrangement 6' has phase shifted control of the inlet valves 18 approximately 60 crank angle degrees upon transitioning from the first state illustrated in Fig. 4a to the second state illustrated in Fig. 4b. According to further embodiments, the cam phaser arrangement 6' may be configured to retard the control of the inlet valves 18 a number of crank angle degrees being within the range of 20 - 85, or within the range of 45 - 60, or within the range of 50 - 70 upon transitioning from the first state to the second state. By retarding control of the inlet valves 18 of the engine 1, less gas is sucked into the cylinder 3 from the air inlet 14 and consequently less gas is pumped from the number of cylinders 3 into the exhaust system 4 of the engine 1.

[0106] According to embodiments herein, the control arrangement 21 is configured to, during idling of the engine 1, switch in an alternating manner between a first and a second mode of operation. The control arrangement 21 is configured to operate the engine 1 in the first mode of operation by controlling the flow control assembly 6 to the first state and controlling the exhaust throttle 5 to the closed state. As understood from the above, the control arrangement 21 may be configured to control the flow control assembly 6 to the first state by controlling the cam phaser arrangement 6' to the first state and/or by controlling the throttle 27 towards a closed state. Moreover, the control arrangement 21 may be configured to control the flow control assembly 6 to the first state by controlling the air inlet throttle 15 towards an open state.

[0107] In this manner, a nominal amount of gas is pumped from the number of cylinders 3 into the exhaust system 4 upon operating the engine 1 in the first mode of operation. The relatively high flow rate of gas pumped from the number of cylinders 3 into the exhaust system 4 and the closing of the exhaust throttle 5 results in an efficient heating of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1, i.e., of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 referred to above. Therefore, the first mode of operation may also be referred to as a heating mode.

[0108] The control arrangement 21 is configured to operate the engine 1 in the second mode of operation by controlling the flow control assembly 6 to the second state and by controlling the exhaust throttle 5 to the open state. As understood from the above, the control arrangement 21 may be configured to control the flow control assembly 6 to the second state by controlling the cam phaser arrangement 6' to the second state and/or by controlling the throttle 27 towards an open state. Moreover, the control arrangement 21 may be configured to control the flow control assembly 6 to the second state by controlling the air inlet throttle 15 towards a closed state.

[0109] In this manner, a reduced amount of gas is pumped from the number of cylinders 3 into the exhaust system 4 upon operating the engine 1 in the second mode of operation. The relatively low flow rate of gas pumped from the number of cylinders 3 into the exhaust system 4 results in a low cooling rate of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1, i.e., of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 referred to above. The controlling of the exhaust throttle 5 to the open state can ensure combustion stability despite a low flow of gas through the engine 1 and a low fuel injection rate in the second mode of operation. Therefore, the second mode of operation, as referred to herein, may also be referred to as a temperature saving mode.

[0110] **Fig. 5** illustrates an upper graph showing temperature data dT1, dT2, dT3 as a function of time t from the first, second, and third temperature sensors T1, T2, T3 of the engine 1 illustrated in Fig. 2, and a lower graph showing a current operational mode m1, m2 of the engine 1 illustrated in Fig. 2.

[0111] Below, simultaneous reference is made to Fig. 1 - Fig. 5, if not indicated otherwise. In the following, the first mode of operation has been assigned the reference sign "m1" and the second mode of operation has been assigned the reference sign "m2".

[0112] In the illustrated example of Fig. 5, the control arrangement 21 receives an idling request, i.e., a request for engine idling, at the time t0. The idling request may be received from an input device in a driver environment of a vehicle 2 comprising the engine 1, such as from an accelerator pedal, and/or from another control device or system of the vehicle 2 comprising the engine 1.

[0113] In Fig. 5, an upper threshold temperature tr2 and a lower threshold temperature tr1 are indicated. According to the illustrated embodiments, the control arrangement 21 is configured to provide a temperature estimate Avg of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1, i.e., of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2, based on the temperature data dT1, dT2, dT3 from the first, second, and third temperature sensors T1, T2, T3 of the engine 1.

[0114] That is, according to the illustrated embodiments, the control arrangement 21 is configured to provide the temperature estimate Avg using input from the first, the second, and the third temperature sensors T1, T2, T3 of the engine 1. According to further embodiments, the control arrangement 21 may be configured to provide the temperature estimate Avg using input from one temperature sensor, or at least two different temperature sensors.

[0115] Moreover, according to some embodiments, the control arrangement 21 may be configured to provide a temperature estimate Avg of one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1 in another manner than by using input from a number of temperature sensors, such as by estimating the temperature estimate Avg for example using data representative of one or more of a current ambient temperature, a current or preceding load of the engine 1, a current or preceding rotational speed of a crankshaft 16 of the engine 1, and the like.

[0116] The temperature estimate Avg of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1 may be representative of an average temperature of the one or more catalytic converters C1, C2 or a weighted average temperature of the one or more catalytic converters C1, C2. As an alternative, the temperature estimate Avg of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1 may be representative of an estimated or sensed temperature of one of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1.

[0117] Moreover, according to the illustrated embodiments, the control arrangement 21 is configured to, upon receipt of an idling request, select between initiating idling of the engine 1 in the first mode of operation m1 or in the second mode of operation m2 based on the temperature estimate Avg. That is, in more detail, according to the illustrated embodiments, the control arrangement 21 is configured to initiate idling of the engine 1 in the first mode of operation m1 if the temperature estimate Avg is below the lower threshold temperature tr1 and is configured to initiate idling of the engine 1 in the second mode of operation m2 if the temperature estimate Avg is above the lower threshold temperature tr1.

[0118] As seen in the illustrated example of Fig. 5 at time to, the temperature estimate Avg is above the lower threshold temperature tr1 and engine idling is therefore initiated in the second mode of operation m2. In this manner, the temperature of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 can be maintained in an efficient manner.

[0119] According to the illustrated embodiments, the control arrangement 21 is configured to switch from the second mode of operation m2 to the first mode of operation m1 when the temperature estimate Avg declines below the lower threshold temperature tr1. As seen in the illustrated example of Fig. 5, the temperature estimate Avg declines below the lower threshold temperature tr1 at time t1 and the control arrangement 21 therefore switches from the second mode of operation m2 to the first mode of operation m1. In this manner, the temperature of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 can be increased in an efficient manner. As seen in the time period following the time t1, the temperature data dT1, dT2, dT3 steadily increases after the switch from the second mode of operation m2 to the first mode of operation m1.

[0120] According to the illustrated embodiments, the control arrangement 21 is configured to switch from the first mode of operation m1 to the second mode of operation m2 when the temperature estimate Avg rises above the upper threshold temperature tr2. As seen in the illustrated example of Fig. 5, the temperature estimate Avg rises above the upper threshold temperature tr2 at time t2 and the control arrangement 21 therefore switches from the first mode of operation m1 to the second mode of operation m2. In this manner, the temperature of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 can again be maintained in an efficient manner.

[0121] According to the illustrated embodiments, the control arrangement 21 is configured to continue the above mentioned control as long as engine idling is requested and the control arrangement 21 therefore switches in an alternating manner between the first and second modes of operation m1, m2 based on the temperature estimate Avg and the upper and lower threshold temperatures tr1, tr2 according to the above described as long as engine idling is requested.

[0122] According to the illustrated embodiments, the lower threshold temperature tr1 is set to 200 degrees Celsius and the upper threshold temperature tr2 is set to 210 degrees Celsius. However, each of the upper and lower threshold temperatures tr1, tr2 may be set to another value. As an example, the lower threshold temperature tr1 may be set to a value between 180 - 220 degrees Celsius, and the upper threshold temperature tr2 may be set to a value between 200 - 280 degrees Celsius.

[0123] In this manner, it can be ensured that an actual temperature of each of the first Selective Catalytic Reduction (SCR) catalyst C1 and the second Selective Catalytic Reduction (SCR) catalyst C2 is maintained above 180 degrees which commonly is a lower threshold temperature below which the conversion efficiency of a catalytic converter is significantly reduced.

[0124] Accordingly, as understood from the above, due to the control performed by the control arrangement 21, conditions are provided for maintaining a temperature of the one or more catalytic converters C1, C2 above such a lower threshold temperature while minimizing the fuel consumption of the engine 1 during engine idling.

[0125] According to some further embodiments, the control arrangement 21 may switch in an alternating manner between the first and second modes of operation m1, m2 without the provision of a temperature estimate Avg of one of the one or more catalytic converters C1, C2 of the exhaust system 4 of the engine 1. Instead, in such embodiments, the control arrangement 21 may be configured to operate the engine 1 in the first and second modes of operation m1, m2 in some determined time periods. Moreover, in such embodiments, the durations of such determined time periods may for example be based on some input data, such as a current ambient temperature, a current or preceding load of the engine 1, a current or preceding rotational speed of a crankshaft 16 of the engine 1, or the like. Also in such embodiments, conditions are provided for maintaining a temperature of the one or more catalytic converters C1, C2 above a lower threshold temperature while minimizing the fuel consumption of the engine 1 during engine idling.

[0126] Fig. 6 schematically illustrates a method 100 of operating an internal combustion engine. The internal combustion engine 1 may be an internal combustion engine 1 according to theembodiments explained with reference to Fig. 1 - Fig. 5 above. Therefore below, simultaneous reference is made to Fig. 1 - Fig. 6, if not indicated otherwise.

[0127] The method 100 is a method of operating an internal combustion engine 1, wherein the method 100 is performed by a control arrangement 21, and wherein the engine 1 comprises a number of cylinders 3, a piston 12 arranged in each cylinder 3 to delimit a combustion chamber 3' inside the cylinder 3, an exhaust system 4 comprising one or more catalytic converters C1, C2 and an exhaust throttle 5 controllable between an open state and a closed state, and a flow control assembly 6 controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders 3 into the exhaust system 4 and a second state to provide a reduced amount of gas pumped from the number of cylinders 3 into the exhaust system 4. The method 100 comprises, during idling of the engine 1:

- operating 110 the engine 1 in a first mode of operation m1 by controlling 111 the flow control assembly 6 to the first state and controlling 112 the exhaust throttle 5 to the closed state,

- operating 120 the engine 1 in a second mode of operation m2 by controlling 121 the flow control assembly 6 to the second state and controlling 122 the exhaust throttle 5 to the open state, and
- switching 130 in an alternating manner between the first and second modes of operation m1, m2.

[0128] Moreover, as indicated in Fig. 6, the method 100 may comprise:

- providing 101 a temperature estimate Avg of at least one of the one or more catalytic converters C1, C2, and
- switching 131 from the first mode of operation m1 to the second mode of operation m2 when the temperature estimate Avg rises above an upper threshold temperature tr2.

[0129] Furthermore, as indicated in Fig. 6, the method 100 may comprise:

- providing 101 a temperature estimate Avg of at least one of the one or more catalytic converters C1, C2, and
- switching 132 from the second mode of operation m2 to the first mode of operation m1 when the temperature estimate Avg declines below a lower threshold temperature tr1.

[0130] Moreover, as indicated in Fig. 6, according to some embodiments, the method 100 comprises:

- providing 101 a temperature estimate Avg of at least one of the one or more catalytic converters C1, C2,

and upon receipt of an idling request:

- selecting 103 between initiating idling of the engine 1 in the first mode of operation m1 or in the second mode of operation m2 based on the temperature estimate Avg.

[0131] According to some embodiments, the step of providing 101 the temperature estimate Avg is performed using input from at least two different temperature sensors T1, T2, T3.

[0132] Moreover, according to some embodiments, the flow control assembly 6 comprises a cam phaser arrangement 6' controllable to regulate the amount of gas pumped from the number of cylinders 3 into the exhaust system 4, and wherein the steps of controlling 111, 121 the flow control assembly 6 to the first and second states are performed by:

- controlling 113, 123 the cam phaser arrangement 6' to phase shift control of at least one of inlet valves 18 and exhaust valves 24 of the engine 1.

[0133] As indicated in Fig. 6, the step of controlling 121 the flow control assembly 6 to the second state may comprise the steps of:

- advancing 124 control of exhaust valves 24 of the engine 1, and
- retarding 125 control of inlet valves 18 of the engine 1.

[0134] Moreover, the step of advancing 124 the control of the exhaust valves 24 may comprise:

- advancing 124' the control of the exhaust valves 24 a number of crank angle degrees being within the range of 20 - 85, or within the range of 50 - 70.

[0135] Furthermore, the step of retarding 125 the control of the inlet valves 18 may comprise:

- retarding 125' the control of the inlet valves 18 a number of crank angle degrees being within the range of 20 - 85, or within the range of 45 - 60.

[0136] According to some embodiments, the engine 1 comprises an exhaust gas recirculation loop 7 configured to recirculate exhaust gas from an exhaust outlet 26 of the engine 1 to an air inlet 14 of the engine 1, and wherein the flow control assembly 6 comprises a throttle 27 controllable to regulate the amount of exhaust gas flowing to the exhaust gas recirculation loop 7. According to such embodiments, the steps of controlling 111, 121 the flow control assembly 6 between the first and second states may be performed by:

- controlling 116, 126 an opening degree of the throttle 27.

[0137] As explained with reference to Fig. 2, according to the illustrated embodiments, the throttle 27 is an EGR-throttle. Moreover, as explained with reference to Fig. 2, according to the illustrated embodiments, the flow control assembly 6 comprises an air inlet throttle 15 arranged in the air inlet duct 14' of the engine 1. According to such embodiments, the steps of controlling 111, 121 the flow control assembly 6 between the first and second states may be performed by:

- controlling an opening degree of the air inlet throttle 15.

[0138] 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 101, 103, 110, 111, 112, 113, 116, 120, 121, 122, 123, 124, 124', 125, 125', 126, 130, 131, and 132 of the method 100.

[0139] **Fig. 7** illustrates a computer-readable medium

200 comprising instructions which, when executed by a computer, cause the computer to carry out the method 100 according to some embodiments of the present disclosure. According to some embodiments, the computer-readable medium 200 comprises 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 some embodiments. The computer may be comprised in the control arrangement 21.

[0140] One skilled in the art will appreciate that the method 100 of operating an internal combustion engine 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 101, 103, 110, 111, 112, 113, 116, 120, 121, 122, 123, 124, 124', 125, 125', 126, 130, 131, 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, such as the computer-readable medium 200 illustrated in Fig. 7. In other words, the computer program product may be a computer readable medium 200 and the computer program may be stored in the computer readable medium 200.

[0141] The control arrangement 21 may comprise a computer which may take the form of substantially any suitable type of hardware or hardware/firmware device implemented using processing circuitry such as, but not limited to, a processor, Central Processing Unit (CPU), a controller, an arithmetic logic unit (ALU), a digital signal processor, an Application Specific Integrated Circuit (ASIC), a circuit for digital signal processing (digital signal processor, DSP), a microcomputer, a field programmable gate array (FPGA), a System-on-Chip (SoC), a programmable logic unit, a microprocessor, an application-specific integrated circuit, or any other device capable of electronically performing operations in a defined manner or other processing logic that may interpret and execute instructions. The herein utilised expression "computer" may represent a processing circuitry comprising a plurality of processing circuits, such as, e.g., any, some or all of the ones mentioned above.

[0142] The control arrangement 21 may further comprise a memory unit, wherein the computer may be connected to the memory unit, which may provide the computer with, for example, stored program code and/or stored data which the computer may need to enable it to do calculations. The computer 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.

[0143] The control arrangement 21 is connected to components of the combustion engine 1 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 computer. One or more output signal sending devices may be arranged to convert calculation results from the computer 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 combustion engine 1 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.

[0144] In the embodiments illustrated, the combustion engine 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.

[0145] 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 and engines of the type here concerned are therefore often provided with significantly more control arrangements than depicted in Fig. 2 and Fig. 3, as one skilled in the art will surely appreciate.

[0146] The computer-readable medium 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 101, 103, 110, 111, 112, 113, 116, 120, 121, 122, 123, 124, 124', 125, 125', 126, 130, 131, and 132 according to some embodiments when being loaded into one or more computers of the control arrangement 21. The data carrier may be, e.g. a CD ROM disc, as is illustrated in Fig. 7, 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. Accordingly, in some embodiments, the computer-readable medium 200 may be a non-transitory computer-readable medium, such as a tangible electronic, magnetic, optical, infrared, electromagnetic, and/or semiconductor system, apparatus, and/or device. The computer-readable medium 200 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.

[0147] The features "advanced" and "advancing", as used herein means that a control or event referred to is performed earlier regarding crank angle degrees or time, as compared to if the control or event would not be advanced. The features "retarded" and "retarding", as used herein means that a control or event referred to is performed later regarding crank angle degrees or time, as compared to if the control or event would not be retarded.

[0148] 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.

[0149] 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 operating an internal combustion engine (1), wherein the method (100) is performed by a control arrangement (21), and wherein the engine (1) comprises:

- a number of cylinders (3),
- a piston (12) arranged in each cylinder (3) to delimit a combustion chamber (3') inside the cylinder (3),
- an exhaust system (4) comprising one or more catalytic converters (C1, C2) and an exhaust throttle (5) controllable between an open state and a closed state, and
- a flow control assembly (6) controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders (3) into the exhaust system (4) and a second state to provide a reduced amount of gas pumped from the number of cylinders (3) into the exhaust system (4),

wherein the method (100) comprises, during idling of the engine (1):

- operating (110) the engine (1) in a first mode of operation (m1) by controlling (111) the flow control assembly (6) to the first state and controlling (112) the exhaust throttle (5) to the closed state,
- operating (120) the engine (1) in a second mode of operation (m2) by controlling (121) the flow control assembly (6) to the second state and controlling (122) the exhaust throttle (5) to the open state, and
- switching (130) in an alternating manner between the first and second modes of operation (m1, m2).

2. The method (100) according to claim 1, wherein the method (100) comprises:

- providing (101) a temperature estimate (Avg) of at least one of the one or more catalytic converters (C1, C2), and
- switching (131) from the first mode of operation (m1) to the second mode of operation (m2) when the temperature estimate (Avg) rises above an upper threshold temperature (tr2).

3. The method (100) according to claim 1 or 2, wherein the method (100) comprises:

- providing (101) a temperature estimate (Avg) of at least one of the one or more catalytic converters (C1, C2), and
- switching (132) from the second mode of operation (m2) to the first mode of operation (m1) when the temperature estimate (Avg) declines below a lower threshold temperature (tr1).

4. The method (100) according to any one of the preceding claims, wherein the method (100) comprises:

- providing (101) a temperature estimate (Avg) of at least one of the one or more catalytic converters (C1, C2), and

upon receipt of an idling request:

- selecting (103) between initiating idling of the engine (1) in the first mode of operation (m1) or in the second mode of operation (m2) based on the temperature estimate (Avg).

5. The method (100) according to any one of the claims 2 - 4, wherein the step of providing (101) the temperature estimate (Avg) is performed using input from at least two different temperature sensors (T1, T2, T3).

6. The method (100) according to any one of the preceding claims, wherein the flow control assembly (6) comprises a cam phaser arrangement (6') controllable to regulate the amount of gas pumped from the number of cylinders (3) into the exhaust system (4), and wherein the steps of controlling (111, 121) the flow control assembly (6) to the first and second states are performed by:

- controlling (113, 123) the cam phaser arrangement (6') to phase shift control of at least one of inlet valves (18) and exhaust valves (24) of the engine (1).

7. The method (100) according to claim 6, wherein the step of controlling (121) the flow control assembly (6) to the second state comprises the steps of:

- advancing (124) control of exhaust valves (24) of the engine (1), and
- retarding (125) control of inlet valves (18) of the engine (1).

8. The method (100) according to claim 7, wherein the step of advancing (124) the control of the exhaust valves (24) comprises:

- advancing (124') the control of the exhaust valves (24) a number of crank angle degrees being within the range of 20 - 85, or within the range of 50 - 70.

9. The method (100) according to claim 7 or 8, wherein the step of retarding (125) the control of the inlet valves (18) comprises:

- retarding (125') the control of the inlet valves (18) a number of crank angle degrees being within the range of 20 - 85, or within the range of 45 - 60.

10. The method (100) according to any one of the preceding claims, wherein the engine (1) comprises an exhaust gas recirculation loop (7) configured to recirculate exhaust gas from an exhaust outlet (26) of the engine (1) to an air inlet (14) of the engine (1),

and wherein the flow control assembly (6) comprises a throttle (27) controllable to regulate the amount of exhaust gas flowing to the exhaust gas recirculation loop (7),
and wherein the steps of controlling (111, 121) the flow control assembly (6) between the first and second states is performed by:

- controlling (116, 126) an opening degree of the throttle (27).

11. A control arrangement (21) for an internal combustion engine (1), and wherein the engine (1) comprises:

- a number of cylinders (3),
- a piston (12) arranged in each cylinder (3) to delimit a combustion chamber (3') inside the cylinder (3),
- an exhaust system (4) comprising one or more catalytic converters (C1, C2) and an exhaust throttle (5) controllable between an open state and a closed state, and
- a flow control assembly (6) controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders (3) into the exhaust system (4) and a second state to provide a reduced amount of gas pumped from the number of cylinders (3) into the exhaust system (4),

wherein the control arrangement (21) is configured to, during idling of the engine (1):

- operate the engine (1) in a first mode of operation (m1) by controlling the flow control assembly (6) to the first state and controlling the exhaust throttle (5) to the closed state,
- operate the engine (1) in a second mode of operation (m2) by controlling the flow control assembly (6) to the second state and controlling the exhaust throttle (5) to the open state, and
- switch in an alternating manner between the first and second modes of operation (m1, m2).

12. A computer program comprising instructions to cause the control arrangement (21) according to claim 11 to execute the steps of the method (100) according to any one of the claims 1-10.

13. A computer-readable medium (200) having stored thereon the computer program of claim 12.

14. An engine (1) comprising:

- a number of cylinders (3),
- a piston (12) arranged in each cylinder (3) to delimit a combustion chamber (3') inside the cylinder (3),
- an exhaust system (4) comprising one or more catalytic converters (C1, C2) and an exhaust throttle (5) controllable between an open state and a closed state, and
- a flow control assembly (6) controllable between a first state to provide a nominal amount of gas pumped from the number of cylinders (3) into the exhaust system (4) and a second state to provide a reduced amount of gas pumped from the number of cylinders (3) into the exhaust

system (4), and
- a control arrangement (21) according to claim 11.

15. A vehicle (2) comprising an engine (1) according to claim 14.

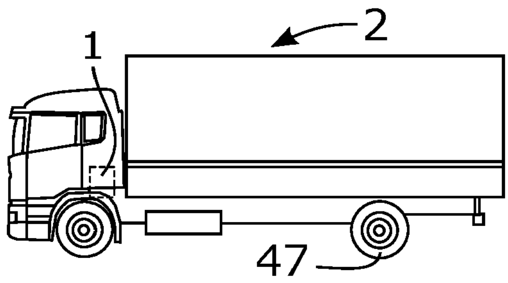
2
1
47

Fig. 1

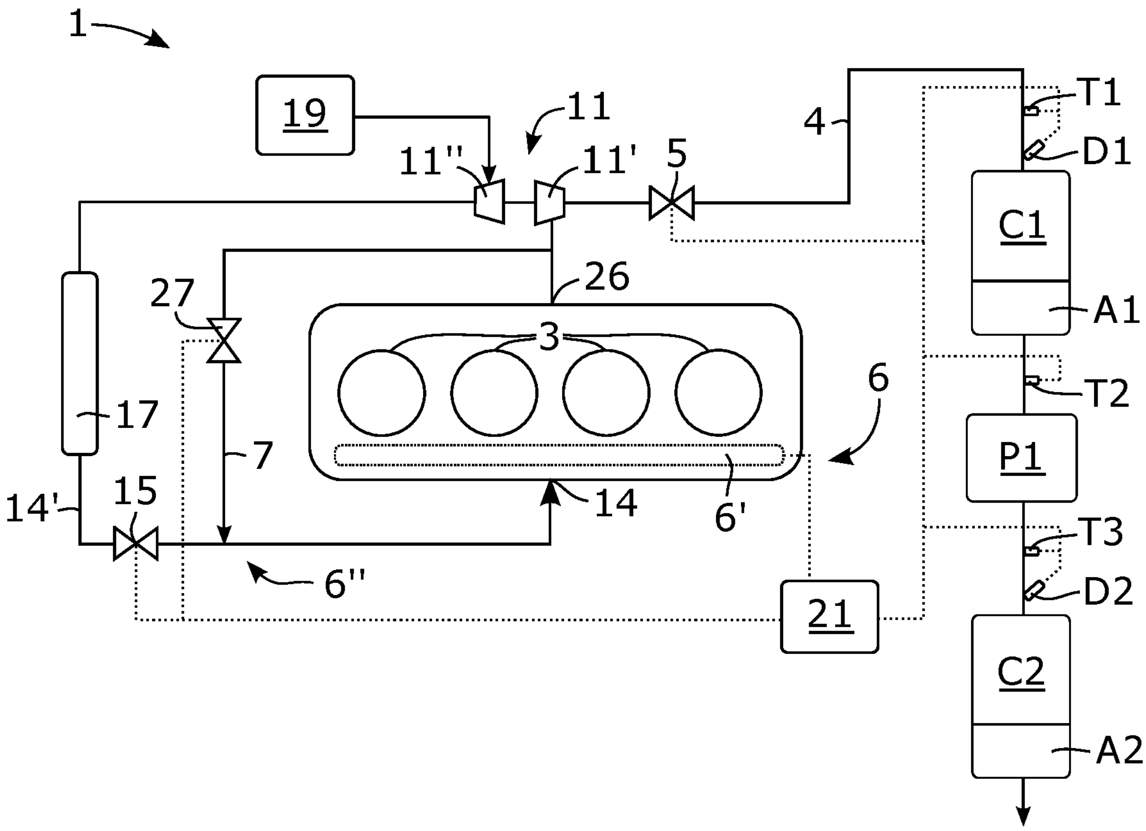
1
19
11
11''
11'
5
4
T1
D1
C1
A1
26
27
3
17
6
T2
P1
7
14
6'
T3
D2
14'
15
6''
21
C2
A2

Fig. 2

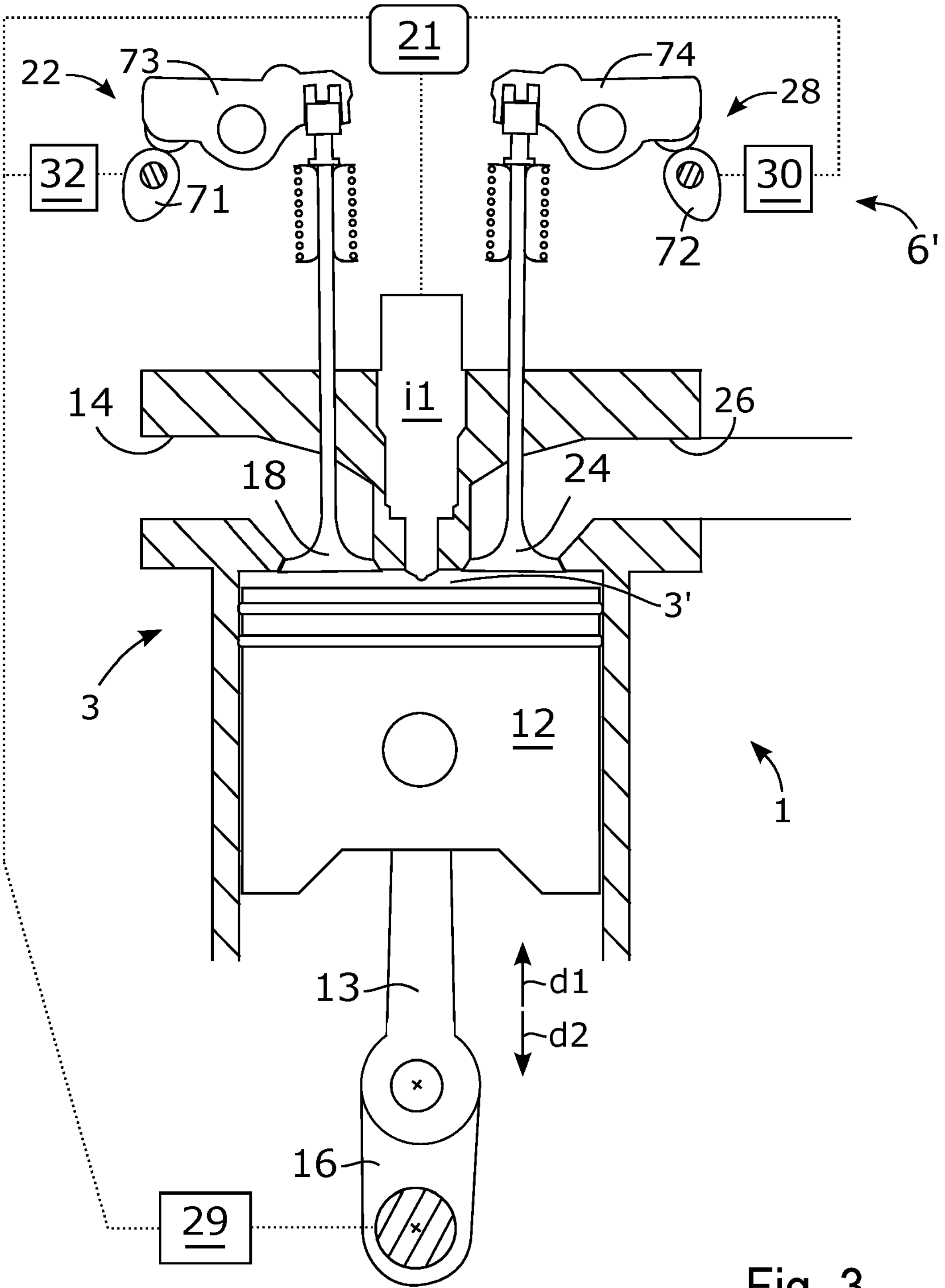

Fig. 3

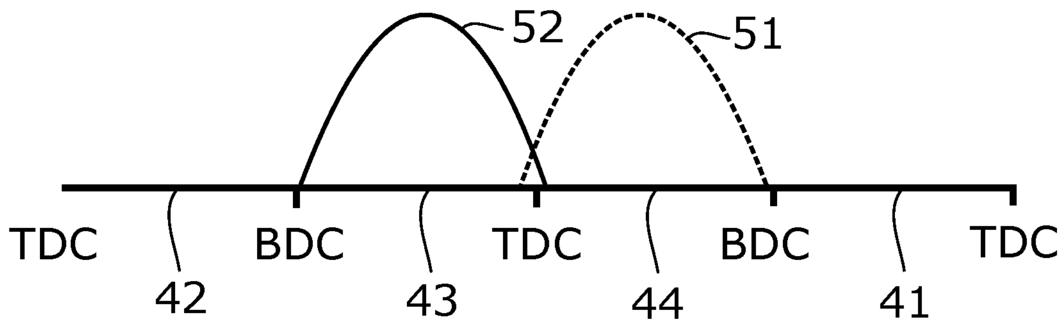

Fig. 4a

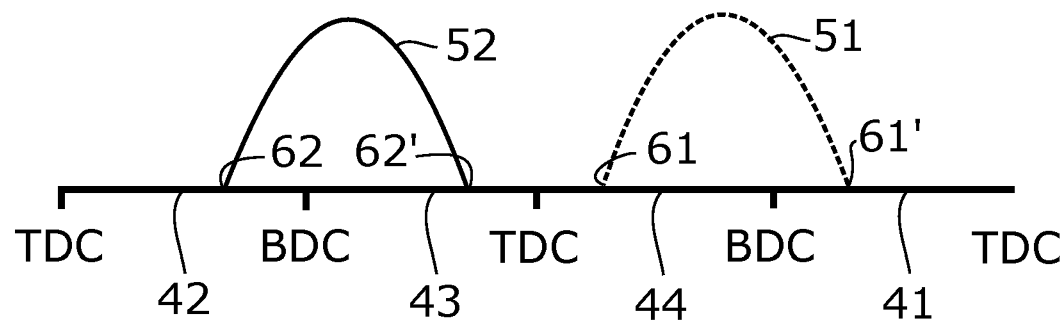

Fig. 4b

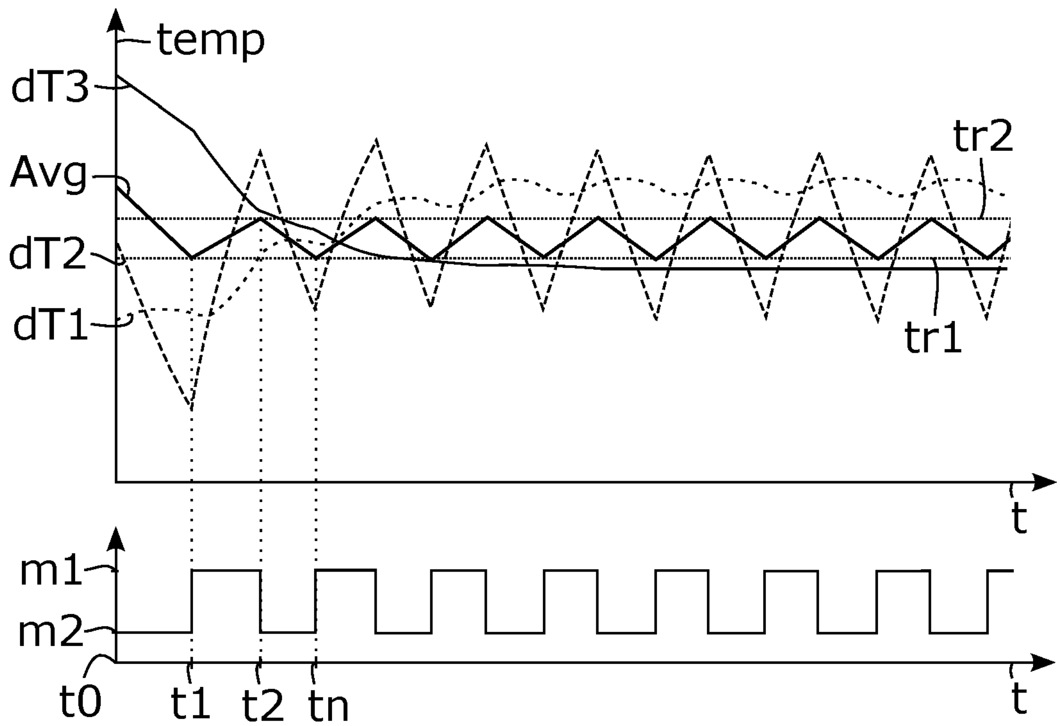

Fig. 5

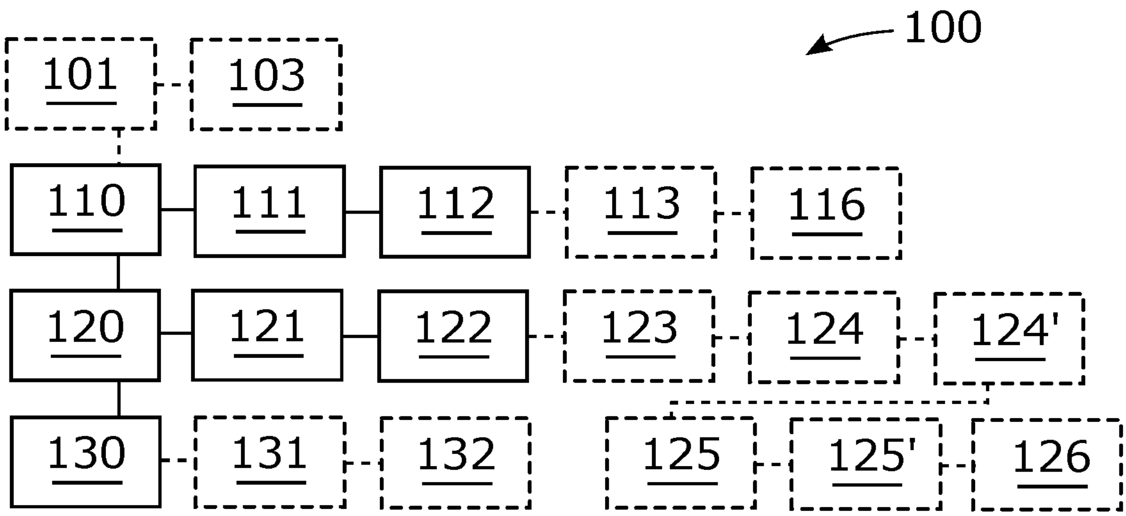
100
101
103
110
111
112
113
116
120
121
122
123
124
124'
130
131
132
125
125'
126

Fig. 6

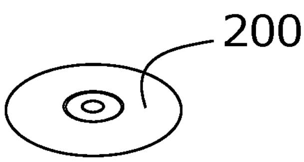
200

Fig. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 18 2740

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 A	EP 3 260 689 A1 (ISUZU MOTORS LTD [JP]) 27 December 2017 (2017-12-27) * claims; figures 1-13 * -----	1,10-15 2-9	INV. F02D41/00 F02D41/02 F02D41/14 F02D41/08 F02D9/08 F02D13/02
X A	JP 2016 153631 A (ISUZU MOTORS LTD) 25 August 2016 (2016-08-25) * paragraphs [0068], [0069], [0070], [0071]; claim 1; figure 1 * -----	1,10-15 2-9	
E	WO 2023/152946 A1 (MITSUBISHI MOTORS CORP [JP]) 17 August 2023 (2023-08-17) * claims 1-6; figure 1 * -----	1-5, 10-15	
A	CN 108 223 181 B (CHINA FAW GROUP CORP) 17 March 2020 (2020-03-17) * figure 1 * -----	1,8,9,11	
A	DE 10 2022 128416 A1 (FORD GLOBAL TECH LLC [US]) 4 May 2023 (2023-05-04) * claims 1-8; figure 1 * -----	1,11	TECHNICAL FIELDS SEARCHED (IPC) F02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	27 November 2023	Boye, Michael

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 18 2740

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.

27-11-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3260689 A1	27-12-2017	CN 107250514 A	13-10-2017
		EP 3260689 A1	27-12-2017
		JP 2016153630 A	25-08-2016
		US 2018038254 A1	08-02-2018
		WO 2016133025 A1	25-08-2016
JP 2016153631 A	25-08-2016	NONE	
WO 2023152946 A1	17-08-2023	NONE	
CN 108223181 B	17-03-2020	NONE	
DE 102022128416 A1	04-05-2023	CN 116066247 A	05-05-2023
		DE 102022128416 A1	04-05-2023
		US 2023139973 A1	04-05-2023

EPO FORM P0459

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