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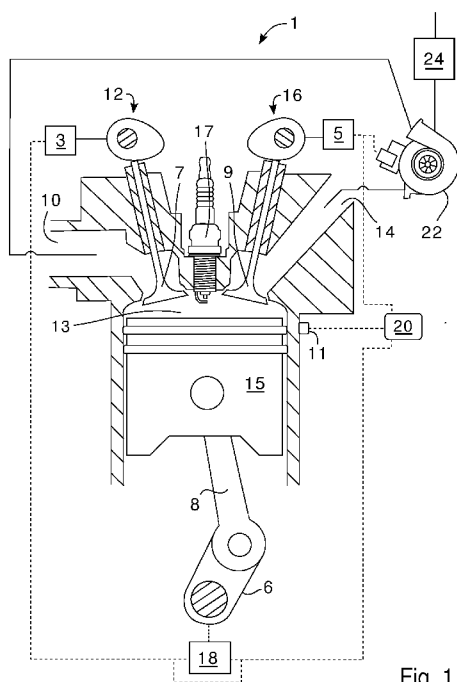


Fig. 1

(57) Abstract: A method (100) of controlling an internal combustion engine (1) is disclosed. The method (100) comprises determining (110) a knock level (kl) in the at least one cylinder (13) of the engine (1), setting (120) an overlap limit (Olim) based on a current overlap (O) used when the determined knock level (kl) exceeds a threshold value (th), and controlling (130) the overlap (O) based on the overlap limit (Olim). The present disclosure further relates to a computer program, a computer-readable medium (200), a control arrangement (20), a combustion engine (1), and a vehicle (30).



Method of Controlling a Combustion Engine, Combustion Engine, and Related Devices

TECHNICAL FIELD

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

10 BACKGROUND

Internal combustion engines, such as four-stroke internal combustion engines operating in the so called Otto-cycle, comprise one or more cylinders and a piston arranged in each cylinder. Otto-engines comprise an ignition device arranged to ignite the air/fuel mixture in the cylinder. The pistons are connected to a crankshaft of the engine and are arranged to
15 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, push rods, or similar. A four-
20 stroke internal combustion engine completes four separate strokes while turning a crankshaft two revolutions. 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.

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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
30 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, by the ignition device. The combustion of fuel within the cylinder significantly increases pressure and temperature in the cylinder. The combustion of the fuel
35 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 crankshaft in 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, because usually, the majority 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. The exhaust stroke is then followed by an inlet stroke. As is further explained herein, the term "overlap" relates to a time, or a number of crank angle degrees, in which inlet valves and outlet valves are open simultaneously in a cylinder. The use of overlap provides some advantages, which is further explained herein, and occurs, if present, in a transition area between the exhaust stroke and the inlet stroke.

In general, a high cylinder pressure at, or close to, the top dead centre of the piston of the engine increases the fuel efficiency of the engine. However, a limiting factor for an Otto engine is engine knock. Engine knock occurs when combustion of some of the air/fuel mixture in the cylinder does not result from propagation of the flame front ignited by the ignition device, but one or more pockets of air/fuel mixture explode outside the envelope of the normal combustion front. The shock wave creates the characteristic metallic "pinging" sound, and cylinder pressure increases dramatically. Engine knock is harmful for an engine and is to be avoided.

As mentioned above, a high cylinder pressure at, or close to, the top dead centre of the piston of the engine increases the fuel efficiency of the engine. However, high cylinder pressures increase the tendency of engine knock. High cylinder pressures at, or close to, the top dead centre of the piston of the engine is achieved by igniting the air/fuel mixture in an early phase of the piston's stroke towards the top dead centre. Conversely, the maximum cylinder pressure in the cylinder can be reduced by igniting the air/fuel mixture later so as to reduce the tendency of engine knock. The tendency of knocking is also affected by other factors, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and more.

In order to obtain a high fuel efficiency, modern Otto-engines are usually provided with a knock sensing device arranged to sense the occurrence of knock, and wherein the ignition device is arranged to postpone the ignition in case knock is detected and is arranged to advance the ignition in case no knock is detected. In this manner, high maximum cylinder pressures can be achieved given the current operating conditions of the engine and given the other factors which affects the tendency of engine knock.

Another challenge faced when designing a combustion engine is to lower emissions produced by the engine. The emission of carbon dioxide (CO_2) is directly correlated with the consumption of fuel of the engine. However, combustion engines produce many more types of substances including nitrogen oxide (NO) and nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter, hydrocarbons (HC), sulphur dioxide (SO_2), and formaldehyde.

Three-way catalytic converters are commonly used by Otto-engines to lower the emissions from the engine. A three-way catalytic converter has three simultaneous tasks, namely reduction of nitrogen oxide (NO) and nitrogen dioxide (NO_2) to nitrogen (N_2), oxidation of carbon monoxide (CO) to carbon dioxide (CO_2), and oxidation of unburnt hydrocarbons (HC) to carbon dioxide (CO_2) and water (H_2O).

Three-way catalytic converters are effective when the engine is operated within a narrow band of air-fuel ratios near the stoichiometric point, such that the exhaust gas composition oscillates between rich (excess fuel) and lean (excess oxygen). Conversion efficiency falls rapidly when the engine is operated outside of this band. Under lean engine operation, the exhaust contains excess oxygen, and the reduction of NO_x is not favoured. Under rich conditions, the excess fuel consumes all of the available oxygen prior to the catalyst, leaving only oxygen stored in the catalyst available for the oxidation function. Therefore, closed-loop engine control systems are used for effective operation of three-way catalytic converters because of the continuous balancing required for effective NO_x reduction and HC oxidation.

Two other factors which affect the operation of a combustion engine are residual gases trapped from a previous combustion cycle and blow through. Blow through is a term used for air blowing through the cylinder from an open inlet valve to an open exhaust valve. These two factors are affected by the overlap between inlet valves and outlet valves of the engine. A great overlap reduces residual gases and increases blow through gases. Contrarywise, a smaller overlap increases residual gases and decreases blow through gases. Some engines operate with a great overlap, which can be advantageous for combustion aspects and can provide cooling of outlet valves of the engine. However, the high amount of blow through gases obtained when using a great overlap increases the amount of oxygen in the exhaust gases. Therefore, in order to preserve function of the three-way catalytic converter, more fuel must be added which increases the fuel consumption and the emissions of the engine.

Some engines comprise a valve control arrangement capable of controlling the overlap between inlet valves and outlet valves of the combustion engine. The amount of blow

through, as well as the amount of residual gases, is difficult to measure or estimate. In a lab-environment, the amount of residual gases and the amount of blow through can be measured using expensive, complex, and sensitive sensors and equipment. However, at present, there are no means for automotive applications available on the market for measuring the amount of residual gases and the amount of blow through.

Furthermore, generally, on today's consumer market, it is an advantage if products, such as combustion engines and their associated arrangements, have conditions and/or characteristics suitable for being manufactured and assembled in a cost-efficient manner.

SUMMARY

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

According to a first aspect of the invention, the object is achieved by a method of controlling an internal combustion engine, wherein the combustion engine comprises a valve control arrangement capable of controlling the overlap between inlet valves and outlet valves of the combustion engine, and a knock sensing arrangement configured to sense the occurrence of knock in at least one cylinder of the combustion engine.

The method comprises:

- determining a knock level in the at least one cylinder,
- setting an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and
- controlling the overlap based on the overlap limit.

Since the method comprises the step of setting an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and the step of controlling the overlap based on the overlap limit, a method is provided capable of obtaining an advantageous overlap at different operating conditions of the engine, in a simple and efficient manner, using input values from a simple and low-cost component, such as a knock sensor, which usually already is comprised in a combustion engine.

Accordingly, a method is provided capable of controlling the combustion engine to operate with a low amount of residual gases in the cylinder and a low amount of blow through gases, without significantly increasing complexity and cost of the engine. That is, conditions are provided for obtaining a minimal overlap sufficiently for flushing away heat and residual

gases from the cylinder while the amount of blow through gases is kept low, without significantly increasing complexity and cost of the engine.

Furthermore, conditions are provided for obtaining an advantageous overlap given varying other factors affecting the combustion in the cylinder, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

Moreover, since a method is provided capable of controlling the combustion engine to operate with a low amount of blow through gases, the need for adding fuel as a result of a high oxygen levels in the exhaust gases is circumvented. As a result thereof, the fuel efficiency of the engine is increased, and the amount of emissions produced by the engine is lowered.

In addition, since a method is provided capable of controlling the combustion engine to operate with a low amount of heat and residual gases in the cylinder, conditions are provided for using an early ignition of an air/fuel mixture in the cylinder. This because a low amount of initial heat and residual gases in the cylinder reduce the tendency of knock and therefore allows for a higher maximum cylinder pressure during combustion. As a result thereof, the fuel efficiency of the engine can be increased, and the amount of emissions produced by the engine can be lowered.

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.

Optionally, the step of controlling the overlap comprises the steps of:

- setting an overlap target value based on the overlap limit, and
- controlling the overlap towards the overlap target value.

Thereby, a method is provided capable of controlling the combustion engine to operate within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low, without significantly increasing complexity and cost of the engine. That is, conditions are provided for operating the combustion engine within a narrow window in which a minimal overlap is obtained sufficiently for flushing away heat and residual gases from the cylinder while the amount of blow through gases is kept low, without significantly increasing complexity and cost of the engine.

In addition, further improved conditions are provided for obtaining an advantageous overlap when other factors affecting the combustion in the cylinder varies, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather
5 conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

Optionally, the step of setting the overlap target value comprises the step of:

- setting the overlap target value to a value being offset from the overlap limit.

10 Thereby, a simple and efficient method is provided capable of controlling the combustion engine to operate within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low, without significantly increasing complexity and cost of the engine. That is, further improved conditions are
15 provided for operating the combustion engine within a narrow window in which a minimal overlap is obtained sufficiently for flushing away heat and residual gases from the cylinder while the amount of blow through gases is kept low, without significantly increasing complexity and cost of the engine.

20 In addition, further improved conditions are provided for obtaining an advantageous overlap when other factors affecting the combustion in the cylinder varies, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

25 Optionally, the overlap target value involves a greater overlap than at the overlap limit.

Thereby, a simple and efficient method is provided capable of controlling the combustion engine to operate within a narrow window in which the amount of residual gases in the
30 cylinder is low and in which the amount of blow through gases is low, without significantly increasing complexity and cost of the engine.

Optionally, the method further comprises:

- updating the overlap limit by reducing the overlap.

35 Thereby, a simple and efficient method is provided capable of controlling the combustion engine to operate within a narrow window in which the amount of residual gases in the

cylinder is low and in which the amount of blow through gases is low, also when the combustion is affected by varying factors, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

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Optionally, the method comprises:

- updating the overlap limit periodically.

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Thereby, a simple and efficient method is provided capable of controlling the combustion engine to operate within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low, also when the combustion is affected by varying factors, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like. This without significantly increasing complexity and cost of the engine.

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Optionally, the method comprises:

- updating the overlap limit with a first frequency in steady state operating conditions of the combustion engine, and
- updating the overlap limit with a second frequency in transient operating conditions of the combustion engine, wherein the second frequency is higher than the first frequency.

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Thereby, a method is provided which updates the overlap limit with a lower frequency in cases where the factors affecting the combustion is less likely to vary, and which updates the overlap limit with a higher frequency in cases where the factors affecting the combustion is more likely to vary. As a result thereof, a simple and efficient method is provided capable of operating a combustion engine with improved fuel efficiency and reduced emissions.

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According to a second aspect of the invention, the object is achieved by a computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments of the present disclosure. Since the computer program comprises instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments 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.

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According to a third aspect of the invention, the object is achieved by a computer-readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the method according to some embodiments of the present disclosure. Since the computer-readable medium comprises instructions which, when the program is executed by a computer, cause the computer to carry out the method according to some embodiments 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.

According to a fourth aspect of the invention, the object is achieved by a control arrangement for controlling an internal combustion engine, wherein the combustion engine comprises a valve control arrangement capable of controlling the overlap between inlet valves and outlet valves of the combustion engine, and a knock sensing arrangement configured to sense the occurrence of knock in at least one cylinder of the combustion engine. The control arrangement is arranged to:

- determine a knock level in the at least one cylinder,
- set an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and
- control the overlap based on the overlap limit.

Since the control arrangement is arranged to set an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and is arranged to control the overlap based on the overlap limit, a control arrangement is provided capable of obtaining an advantageous overlap at different operating conditions of the combustion engine, in a simple and efficient manner, using input values from a simple and low-cost component, such as a knock sensor, which usually already is comprised in a combustion engine.

Accordingly, a control arrangement is provided capable of controlling the combustion engine to operate with a low amount of residual gases in the cylinder and a low amount of blow through gases, without significantly increasing complexity and cost of the engine. That is, conditions are provided for obtaining a minimal overlap sufficiently for flushing away heat and residual gases from the cylinder while the amount of blow through gases is kept low, without significantly increasing complexity and cost of the engine.

Furthermore, conditions are provided for obtaining an advantageous overlap given varying other factors affecting the combustion in the cylinder, such as the temperature of the engine,

the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

Moreover, since a control arrangement is provided capable of controlling the combustion engine to operate with a low amount of blow through gases, the need for adding fuel as a result of a high oxygen levels in the exhaust gases is circumvented. As a result thereof, the fuel efficiency of the engine is increased, and the amount of emissions produced by the engine is lowered.

In addition, since a control arrangement is provided capable of controlling the combustion engine to operate with a low amount of heat and residual gases in the cylinder, conditions are provided for using an early ignition of an air/fuel mixture in the cylinder. This because a low amount of initial heat and residual gases in the cylinder reduce the tendency of knock and therefore allows for a higher maximum cylinder pressure during combustion. As a result thereof, the fuel efficiency of the engine can be increased, and the amount of emissions produced by the engine can be lowered.

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.

According to a fifth aspect of the invention, the object is achieved by an internal combustion engine comprising at least one cylinder, a piston arranged in each cylinder, at least one inlet valve at each cylinder, at least one outlet valve at each cylinder, a valve control arrangement capable of controlling the overlap between the inlet valves and the outlet valves of the combustion engine, a knock sensing arrangement configured to sense the occurrence of knock in at least one cylinder of the combustion engine, and a control arrangement. The control arrangement is arranged to:

- determine a knock level in the at least one cylinder,
- setting an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and
- control the overlap based on the overlap limit.

Since the control arrangement of the internal combustion engine is arranged to set an overlap limit based on a current overlap used when the determined knock level exceeds a threshold value, and is arranged to control the overlap based on the overlap limit, an advantageous overlap at different operating conditions of the combustion engine can be

achieved, in a simple and efficient manner, using input values from a simple and low-cost component, such as a knock sensor.

Accordingly, a combustion engine is provided capable of operating with a low amount of residual gases in the cylinder and a low amount of blow through gases, without significantly increasing complexity and cost of the engine. That is, conditions are provided for obtaining a minimal overlap sufficiently for flushing away heat and residual gases from the cylinder while the amount of blow through gases is kept low, without significantly increasing complexity and cost of the engine.

Furthermore, conditions are provided for obtaining an advantageous overlap given varying other factors affecting the combustion in the cylinder, such as the temperature of the engine, the quality of the fuel, the load of the engine, the inlet manifold pressure, weather conditions, altitude, and the like, without significantly increasing complexity and cost of the engine.

Moreover, since a combustion engine is provided capable of operating with a low amount of blow through gases, the need for adding fuel as a result of a high oxygen levels in the exhaust gases is circumvented. As a result thereof, the fuel efficiency of the engine can be increased, and the amount of emissions produced by the engine can be lowered.

In addition, since a combustion engine is provided capable of operating with a low amount of heat and residual gases in the cylinder, conditions are provided for using an early ignition of an air/fuel mixture in the cylinder. This because a low amount of initial heat and residual gases in the cylinder reduce the tendency of knock and therefore allows for a higher maximum cylinder pressure during combustion. As a result thereof, the fuel efficiency of the engine can be increased, and the amount of emissions produced by the engine can be lowered.

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

Optionally, the valve control arrangement comprises:

- an inlet valve phase-shifting device configured to phase-shift control of the at least one inlet valve, and
- an outlet valve phase-shifting device configured to phase-shift control of the at least one outlet valve.

Thereby, conditions are provided for controlling the overlap by phase-shifting control of the at least one inlet valve and the at least one outlet valve, i.e. with a high degree of control.

- 5 Optionally, the valve control arrangement is configured to control the overlap by phase-shifting control of the at least one inlet valve and the at least one outlet valve. Thereby, the overlap can be controlled with a high degree of control to ensure that the combustion engine is operated within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low.
- 10 Optionally, the combustion engine comprises at least one ignition device in each cylinder of the combustion engine. Thereby, conditions are provided for using an early ignition by the at least one ignition device of an air/fuel mixture in the cylinder.
- 15 Optionally, the combustion engine is specifically adapted to run on a gaseous fuel. Residual gases have a greater effect on the tendency of knock when operating an engine on a gaseous fuel, as compared to when operating an engine on gasoline fuel. This because a gaseous fuel is more resistant to high temperatures and pressures than gasoline, and the residual gases will therefore have a greater effect on the tendency of knock. However, since
- 20 the control arrangement of the combustion engine is capable of operating the combustion engine within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low, the combustion engine can be operated at high power levels with high fuel efficiency and low emission levels.
- 25 Optionally, the combustion engine is specifically adapted to run on an alcohol based fuel. Residual gases obtained when operating an engine on an alcohol based fuel have a greater effect on the tendency of knock than residual gases obtained when operating an engine on gasoline. Residual gases have a greater effect on the tendency of knock when operating an engine on an alcohol based fuel, as compared to when operating an engine on gasoline fuel.
- 30 This because an alcohol based fuel is more resistant to high temperatures and pressures than gasoline, and the residual gases will therefore have a greater effect on the tendency of knock. However, since the control arrangement of the combustion engine is capable of operating the combustion engine within a narrow window in which the amount of residual gases in the cylinder is low and in which the amount of blow through gases is low, the
- 35 combustion engine can be operated at high power levels with high fuel efficiency and low emission levels.

According to a sixth aspect of the invention, the object is achieved by a vehicle comprising a combustion engine according to some embodiments of the present disclosure. Since the vehicle comprises a combustion engine according to some embodiments described herein, a vehicle 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.

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

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 cross sectional view of an internal combustion engine, according to some embodiments,

Fig. 2a and Fig. 2b illustrate opening events of at least one inlet valve and at least one exhaust valve in two different operational modes of the combustion engine illustrated in Fig. 1,

Fig. 3 illustrates a diagram illustrating control of overlap performed by a control arrangement of the combustion engine illustrated in Fig. 1,

Fig. 4 illustrates vehicle according to some embodiments,

Fig. 5 illustrates a method of controlling an internal combustion engine, and

Fig. 6 illustrates a computer program product.

DETAILED DESCRIPTION

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

Fig. 1 schematically illustrates a cross sectional view of an internal combustion engine 1, according to some embodiments. Herein, the internal combustion engine 1 is in some cases referred to as “the combustion engine 1” and “the engine 1” for the reason of brevity and/or clarity. The engine 1 comprises at least one cylinder 13 and a piston 15 arranged in each cylinder 13. The piston 15 is connected to a crankshaft 6 via a connecting rod 8. The piston 15 moves forwards and backwards in the cylinder 13 upon rotation of the crankshaft 6,

between a top dead centre TDC and a bottom dead centre BDC. The engine 1 comprises an inlet system 10, which in the illustrated example embodiments is illustrated as an inlet duct. The inlet system 10 may comprise further components such as an air filter, a throttle, a fuel injector, an air flow sensor, and the like.

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The engine 1 further comprises at least one inlet valve 7 arranged in each cylinder 13, which at least one inlet valve 7 is connected with the inlet system 10. The inlet valve 7 is arranged to control flow of gas into the cylinder 13. The engine 1 further comprises an inlet valve control arrangement 12 configured to control each inlet valve 7 on the basis of a rotational position of the crankshaft 6. The engine 1 further comprises at least one exhaust valve 9 arranged in each cylinder 13, which at least one exhaust valve 9 is connected with an exhaust outlet 14 of the engine 1. The exhaust valve 9 is arranged to control flow of gas out of the cylinder 13. The engine 1 further comprises an exhaust valve control arrangement 16 configured to control each exhaust valve 9 on the basis of the rotational position of the crankshaft 6.

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In Fig. 1, the at least one inlet valve 7 and the at least one exhaust valve 9 are illustrated in a respective partially open position. In the partially open position, as well as in a fully open position, the at least one inlet valve 7 is lifted from valve seat thereof and allows flow of gas from the inlet system 10 into the cylinder 13. Likewise, in the partially open position, as well as in a fully open position, the at least one exhaust valve 9 is lifted from valve seat thereof and allows flow of gas from the cylinder 13 to the exhaust outlet 14. As is further explained below, in Fig. 1, the piston 15 is illustrated in a position corresponding to a transition area between an exhaust stroke and an inlet stroke of the engine 1. Since the at least one inlet valve 7 and the at least one exhaust valve 9 are open simultaneously, the engine 1 illustrated in Fig. 1 is operating with a certain amount of overlap.

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In a closed position, each valve 7, 9 abuts against a respective valve seat to close fluid connection between the cylinder 13 and the respective inlet system 10 and the exhaust outlet 14. Each valve 7, 9 may be biased towards the closed position, for example by a spring. The inlet valve control arrangement 12 is arranged to control the at least one inlet valve 7 between the closed position and an open position by displacing the at least one inlet valve 7 in a direction into the cylinder 13. Likewise, the exhaust valve control arrangement 16 is arranged to control the at least one exhaust valve 9 between the closed position and an open position by displacing the at least one exhaust valve 9 in a direction into the cylinder 13. According to the illustrated embodiments, the at least one exhaust valve 9, as well as the at

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least one inlet valve 7, comprises a poppet valve, which also may be referred to as a mushroom valve.

The exhaust valve control arrangement 16 and the inlet valve control arrangement 12 may each comprise one or more camshafts rotatably connected to the crankshaft 6, wherein the camshafts comprises cam lobes arranged to displace valves 7, 9 to an open position by pressing on valve stems of the valves 7, 9 upon rotation of the camshaft. The cam lobes may press directly onto the valve stems of the valves 7, 9, or may press onto the valve stems of the valves 7, 9 via further arrangements such as push rods, rocker arms, hydraulic arrangements, or the like. The exhaust valve control arrangement 16, and/or the inlet valve control arrangement 12, may according to further embodiments comprise electric, pneumatic, or hydraulic actuators arranged to control the valves 7, 9 on the basis of the rotational position of the crankshaft 6. The rotational position of the crankshaft 6 may be obtained using a crank angle sensor 18.

The combustion engine 1 comprises at least one ignition device 17 in each cylinder 13 of the engine 1. According to the illustrated embodiments, the ignition device 17 is a spark plug. However, according to further embodiments, the combustion engine 1 may comprise one or more other types of ignition devices in each cylinder 13, such as a plasma or microwave ignition device. The ignition device 17 is arranged to ignite an air/fuel mixture in the cylinder 13 so as to initiate combustion in the cylinder 13. According to the illustrated embodiments, the engine is an Otto engine operating with a spark plug. Such an engine may also be referred to as a spark-ignition engine (SI engine).

The engine 1 further comprises a fuel supply arrangement, such as one or more fuel injectors. The fuel supply arrangement is not illustrated in Fig. 1 for the reason of brevity and clarity. The fuel may be directly injected into the cylinder 13 using a fuel injector or may be added to incoming air prior to entering the cylinder 13, for example by a fuel injector arranged at the inlet system 10 of the engine 1.

The engine 1 further comprises a valve control arrangement 3, 5 capable of controlling the overlap between the inlet valves 7 and the outlet valves 9 of the combustion engine 1. The valve control arrangement 3, 5 is configured to control the overlap by phase-shifting control of the at least one inlet valve 7 and the at least one outlet valve 9.

According to the illustrated embodiments, the valve control arrangement 3, 5 comprises an inlet valve phase-shifting device 3 configured to phase-shift control of the at least one inlet

valve 7. Moreover, according to the illustrated embodiments, the valve control arrangement 3, 5 comprises an outlet valve phase-shifting device 5 configured to phase-shift control of the at least one outlet valve 9. That is, the inlet valve phase-shifting device 3 is configured to phase-shift control of the at least one inlet valve 7 in relation to the rotational position of crankshaft 6. The exhaust valve phase-shifting device 5 is configured to phase-shift control of the at least one outlet valve 9 in relation to the rotational position of the crankshaft 6.

The exhaust valve phase-shifting device 5 and the inlet valve phase-shifting device 3 may each comprise a hydraulic arrangement, for example using engine oil as hydraulic fluid, to phase-shift control of the valves 7, 9 in relation to the crankshaft 6. Such hydraulic arrangement may form part of a belt pulley (not illustrated) arranged to transfer rotation from the crankshaft 6 to a camshaft of the exhaust valve control arrangement 16 and/or the inlet valve control arrangement 12, wherein the hydraulic arrangement is arranged to regulate an angular relationship between a first portion of the belt pulley, being connected to the crankshaft 6, and a second portion of the belt pulley, being connected to the camshaft, in order to phase-shift control of the at least one inlet valve 7 and/or the at least one exhaust valve 9. In embodiments wherein the exhaust valve control arrangement 16 and/or the inlet valve control arrangement 12 comprises electric, pneumatic, or hydraulic actuators, the phase-shift of control of the at least one inlet valve 7 and/or the at least one exhaust valve 9 may be performed in other manners, for example by an electronic phase-shift of control.

The engine 1 further comprises a knock sensing arrangement 11 configured to sense the occurrence of knock in at least one cylinder 13 of the combustion engine 1. According to the illustrated embodiments, the knock sensing arrangement 11 comprises a knock sensor. The knock sensing arrangement 11 may comprise a vibration sensor, such as a piezo-electric sensor. However, according to further embodiments, the knock sensing arrangement 11 may comprise another type of device for sensing the occurrence of knock in at least one cylinder 13 of the combustion engine 1, such as a microphone, a pressure sensor, an inductive resonant sensor, and/or a device measuring ionization over at least one ignition device 17 of the engine 1.

The engine 1 further comprises a control arrangement 20 connected to the valve control arrangement 3, 5 and the knock sensing arrangement 11. The features and functions of the control arrangement are explained in detail below.

According to the illustrated embodiments, the engine 1 comprises a charging device 22 arranged to compress air to the inlet system 10. The charging device 22 illustrated is a turbo-

charger comprising a turbine arranged to be driven by gases from the exhaust outlet 14. The turbine is arranged at a shaft connected to a compressor wheel which is arranged to compress air to the inlet system 10. The engine 1 may comprise another type of charging device, such as a compressor arranged to be driven by the crankshaft 6 of the engine 1.

5 According to the illustrated embodiments, the control unit 20 is connected to the charging device 22. The control unit 20 is configured to regulate the charge air pressure of the charging device 22 by regulating a waste gate valve of the charging device 22. According to further embodiments, the charging device 22 may be a Variable-geometry turbocharger (VGT). In such embodiments, the control unit 20 may be configured to regulate the charge air
10 pressure of the charging device 22 by regulating geometry of an inlet portion of the turbine of the turbocharger, for example by regulating angular positions of vanes arranged at the inlet portion of the turbine.

According to the illustrated embodiments, the engine 1 comprises an exhaust after treatment
15 system 24 in the form of a Three-Way Catalyst (TWC).

Fig. 2a and **Fig. 2b** illustrate opening events 51, 52 of the at least one inlet valve 7 and the at least one exhaust valve 9 in two different operational modes of the combustion engine 1 illustrated in Fig. 1. Therefore, below, simultaneous reference is made to Fig. 1, Fig. 2a, and
20 Fig. 2b. The curves illustrated in Fig. 2a and Fig. 2b illustrate opening events performed during two revolutions of the crank shaft 6, 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. During the compression stroke 41 and the expansion stroke 42, the at least one inlet valve 7
25 and the at least one exhaust valve 9 are closed. When the piston reaches the bottom dead centre BDC at the end of the expansion stroke 42, the exhaust valve control arrangement 16 controls the at least one exhaust valve 9 to an open position to allow exhaust gases to be expelled from the cylinder 13 to the exhaust outlet 14 during the exhaust stroke 43. When the piston 15 has passed the top dead centre TDC, the exhaust valve control arrangement 16
30 controls the at least one exhaust valve 9 to the closed position early in the inlet stroke 44.

Further, the inlet valve control arrangement 12 controls the at least one inlet valve 7 to an open position to allow air, or an air/fuel mixture, to enter the cylinder 13 during the inlet stroke 44. As can be seen in Fig. 2a and Fig. 2b, the opening event of the at least one inlet
35 valve 7 occurs before the piston 15 has passed the top dead centre TDC in the exhaust stroke 43. Accordingly, in Fig. 2a and in Fig. 2b, the engine 1 is operating with an overlap O between inlet valves 7 and outlet valves 9 of the combustion engine 1. However, as seen

when comparing Fig. 2a and in Fig. 2b, the overlap O is greater in the operational mode illustrated in Fig. 2a than the operational mode illustrated in Fig. 2b. The overlap O may be defined as a time, or a number of crank angle degrees, in which inlet valves 7 and outlet valves 9 are at least partially open simultaneously. According to the illustrated embodiments, the valve control arrangement 3, 5 has reduced the overlap O in Fig. 2b, as compared to Fig. 2a, by advancing control of the at least one outlet valve 9 such that the at least one outlet valve 9 closes earlier, and by retarding control of the at least one inlet valve 7 such that the at least one outlet valve 9 opens later. According to further embodiments, and/or in some operational conditions of the combustion engine 1, the valve control arrangement 3, 5 may reduce the overlap O by phase-shifting control of one of the at least one inlet valve 7 and the at least one outlet valve 9.

Similarly, when comparing Fig. 2a with Fig. 2b, the valve control arrangement 3, 5 has increased the overlap O in Fig. 2a in relation to Fig. 2b, by retarding control of the at least one outlet valve 9 such that the at least one outlet valve 9 closes later, and by advancing control of the at least one inlet valve 7 such that the at least one inlet valve 7 opens earlier. According to further embodiments, and/or in some operational conditions of the combustion engine 1, the valve control arrangement 3, 5 may increase the overlap O by phase-shifting control of one of the at least one inlet valve 7 and the at least one outlet valve 9. Towards the end of the inlet stroke 44, the inlet valve control arrangement 12 controls the at least one inlet valve 7 to a closed position to allow compression of the air, or the air/fuel mixture, in the subsequent compression stroke 41.

Fig. 3 illustrates a diagram illustrating control of the overlap O performed by the control arrangement 20 illustrated in Fig. 1. Below, simultaneous reference is made to Fig. 1, Fig. 2a, Fig. 2b and Fig. 3. The x-axis of the diagram illustrated in Fig. 3 shows the overlap O between inlet valves 7 and outlet valves 9 of the combustion engine 1. The overlap O increases along the extension of the x-axis in the diagram illustrated in Fig. 3. The y-axis of the diagram illustrated in Fig. 3 shows the amount of residual gases Res trapped in the cylinder 13 from a previous combustion cycle and the amount of blow through gases B obtained. The amount of blow through gases B obtained can be defined as the amount of air blowing the through the cylinder 13 from an open at least one inlet valve 7 to an open at least one exhaust valve 9 in the transition area between the exhaust stroke 43 and the inlet stroke 44 of the engine 1. The amount of residual gases Res and the amount of blow through gases B increase along the extension of the y-axis in the diagram illustrated in Fig. 3.

The control arrangement 20 is arranged to determine a knock level kl in the at least one cylinder 13 and to set an overlap limit $Olim$ based on a current overlap O used when the determined knock level kl exceeds a threshold value th . In Fig. 3, the determined knock level kl exceeds the threshold value th at the point indicated with the reference sign " $kl=th$ ". The control arrangement 20 may determine the knock level kl using input values from the knock sensing arrangement 11. The threshold value th of the knock level kl may be selected to a threshold value in which it is estimated that the knock level kl is not harmful to the engine 1. As is further explained herein, the control arrangement 20 is arranged to control the overlap O based on the overlap limit $Olim$. According to the illustrated embodiments, this is achieved by the control arrangement 20 being arranged to set an overlap target value Ot based on the overlap limit $Olim$ and controlling the overlap O towards the overlap target value Ot . As can be seen in Fig. 3, the overlap target value Ot is offset from the overlap limit $Olim$ and involves a greater overlap O than at the overlap limit $Olim$.

In this manner, the control arrangement 20 is capable of controlling the overlap O within a narrow window in which the amount of residual gases Res in the cylinder 13 is low and in which the amount of blow through gases B is low at different operating conditions of the engine 1. Moreover, this is achieved in a simple and efficient manner, using input values from a simple and low-cost component, such as a knock sensor 11, which usually already is comprised in a combustion engine 1. The window, as referred to herein, is delimited in Fig. 3 by the overlap limit $Olim$, in which determined knock level kl exceeds a threshold value th , and an upper overlap limit $Olim2$, in which the blow through gases B exceeds a threshold value. As understood from the above, due to the control of the overlap O by the control arrangement 20 based on the overlap limit $Olim$, there is no need for measuring or detecting when the upper overlap limit $Olim2$ is reached. Thereby, the need for complex and costly sensors is circumvented.

Moreover, the control arrangement 20 is capable of controlling the overlap O within a narrow window in which a minimal overlap O is obtained sufficiently for flushing away heat and residual gases Res from the cylinder 13 while the amount of blow through gases B is kept low. As a result thereof, the ignition device 17 can ignite the air/fuel mixture in the cylinder 13 earlier than would be the case otherwise. Moreover, a higher charge air pressure by the charging device 22 is allowed for. As a result thereof, the combustion engine 1 can be operated at high power levels with high fuel efficiency with a lower tendency of knock.

Moreover, since the control arrangement 20 is capable of controlling the overlap O within a narrow window in which the amount of blow through gases B is low, the need for adding supplemental fuel to the cylinder 13 so as to counteract increased oxygen levels in the

exhaust gases is circumvented. As a result thereof, the combustion engine 1 can be operated at high power levels with high fuel efficiency and low emission levels. Furthermore, due to the control of the overlap O by the control arrangement 20, an automatic adaptation of the overlap O can be made in cases where other factors affecting the combustion in the cylinder 13 vary.

According to some embodiments, the control arrangement 20 is arranged to update the overlap limit O_{lim} by reducing the overlap O. According to these embodiments, the control arrangement 20 may reduce the overlap O when the knock level k_l is below the threshold value th . Such a reduction may be performed periodically, incrementally, and/or continuously. When the determined knock level k_l exceeds the threshold value th as a result of the reduced overlap O, the control arrangement 20 set an updated overlap limit O_{lim} based on the current overlap O used.

According to some embodiments, the control arrangement 20 may update the overlap limit O_{lim} with a first frequency in steady state operating conditions of the combustion engine 1 and update the overlap limit O_{lim} with a second frequency in transient operating conditions of the combustion engine 1, wherein the second frequency is higher than the first frequency. As a result thereof, the control arrangement 20 updates the overlap limit O_{lim} with a lower frequency in cases where the factors affecting the combustion is less likely to vary, and which updates the overlap limit O_{lim} with a higher frequency in cases where the factors affecting the combustion is more likely to vary.

According to some embodiments of the present disclosure, the combustion engine 1, as referred to herein, is specifically adapted to run on a gaseous fuel. Residual gases have a greater effect on the tendency of knock when operating an engine 1 on a gaseous fuel, as compared to when operating an engine on gasoline fuel. However, since the control arrangement 20 of the combustion engine 1 is capable of operating the combustion engine 1 within a narrow window in which the amount of residual gases Res in the cylinder 13 is low and in which the amount of blow through gases B is low, the combustion engine 1 can be operated at high power levels with high fuel efficiency and low emission levels.

According to some further embodiments of the present disclosure, the combustion engine 1, as referred to herein, is specifically adapted to run on an alcohol based fuel. Residual gases obtained when operating an engine 1 on an alcohol based fuel have a greater effect on the tendency of knock than residual gases obtained when operating an engine on gasoline. However, since the control arrangement 20 of the combustion engine 1 is capable of

operating the combustion engine 1 within a narrow window in which the amount of residual gases Res in the cylinder 13 is low and in which the amount of blow through gases B is low, the combustion engine 1 can be operated at high power levels with high fuel efficiency and low emission levels.

5

Fig. 4 illustrates vehicle 30 according to some embodiments. The vehicle 30 comprises a combustion engine 1 according to the embodiments illustrated in Fig. 1. The combustion engine 30 is arranged to provide motive power to the vehicle 30 via wheels 32 of the vehicle. The vehicle 30 illustrated in Fig. 4 is a truck. However, the combustion engine 1, as referred to herein, may be comprised in another 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.

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Fig. 5 illustrates a method 100 of controlling an internal combustion engine 1. The engine 1 may be a combustion engine 1 according to the embodiments illustrated in Fig. 1, and some features, functions and advantages are explained with reference to Fig. 2a, Fig. 2b, and Fig. 3. Therefore, below, simultaneous reference is made to Fig. 1, Fig. 2a, Fig. 2b, and Fig. 3. The method 100 is a method 100 of controlling an internal combustion engine 1, wherein the combustion engine 1 comprises a valve control arrangement 3, 5 capable of controlling the overlap O between inlet valves 7 and outlet valves 9 of the combustion engine 1, and a knock sensing arrangement 11 configured to sense the occurrence of knock in at least one cylinder 13 of the combustion engine 1. The method 100 comprises:

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- determining 110 a knock level kl in the at least one cylinder 13,
- setting 120 an overlap limit Olim based on a current overlap O used when the determined knock level kl exceeds a threshold value th, and
- controlling 130 the overlap O based on the overlap limit Olim.

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As illustrated in Fig. 5, the step of controlling 130 the overlap O may comprise the steps of:

- setting 132 an overlap target value Ot based on the overlap limit Olim, and
- controlling 134 the overlap O towards the overlap target value Ot.

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Moreover, as illustrated in Fig. 5, the step of setting 132 the overlap target value Ot comprises the step of:

- setting 133 the overlap target value Ot to a value being offset from the overlap limit Olim.

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As illustrated in Fig. 5, the method 100 may further comprise:

- updating 140 the overlap limit Olim by reducing the overlap O.

Moreover, as illustrated in Fig. 5, the method 100 may further comprise:

- updating 142 the overlap limit O_{lim} periodically.

5 Furthermore, as illustrated in Fig. 5, the method 100 may further comprise:

- updating 143 the overlap limit O_{lim} with a first frequency in steady state operating conditions of the combustion engine 1, and
 - updating 144 the overlap limit O_{lim} with a second frequency in transient operating conditions of the combustion engine 1, wherein the second frequency
- 10 is higher than the first frequency.

It will be appreciated that the various embodiments described for the method 100 are all combinable with the control arrangement 20 as described herein. That is, the control arrangement 20 may be configured to perform any one of the method steps 110, 120, 130, 132, 133, 134, 140, 142, 143, and 144 of the method 100.

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Fig. 6 illustrates a computer program product 200 for performing a method 100 of controlling an internal combustion engine 1, as illustrated in Fig. 1, wherein the computer program product 200 comprises computer readable code configured to cause a central processing unit of a control arrangement 20 of the engine 1 to perform the method 100 as illustrated in Fig. 5.

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Further, the computer program product 200 comprises a computer program for performing a method 100 of controlling an internal combustion engine 1, as illustrated in Fig. 1, wherein the computer program comprises computer readable code configured to cause a central processing unit of a control arrangement 20 of the engine 1 to perform the method 100 as illustrated in Fig. 5.

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One skilled in the art will appreciate that the method of controlling 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 control arrangement 20, ensures that the control arrangement 20 carries out the desired control, such as the method steps 110, 120, 130, 132, 133, 134, 140, 142, 143, and 144 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.

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The control arrangement 20 may comprise a calculation unit which may take the form of substantially any suitable type of processor circuit or microcomputer, e.g. a circuit for digital signal processing (digital signal processor, DSP), a Central Processing Unit (CPU), a processing unit, a processing circuit, a processor, an Application Specific Integrated Circuit (ASIC), a microprocessor, or other processing logic that may interpret and execute instructions. The herein utilised expression "calculation unit" may represent a processing circuitry comprising a plurality of processing circuits, such as, e.g., any, some or all of the ones mentioned above.

The control arrangement 20 may further comprise a memory unit, wherein the calculation unit may be connected to the memory unit, which may provide the calculation unit with, for example, stored program code and/or stored data which the calculation unit may need to enable it to do calculations. The calculation unit may also be adapted to store partial or final results of calculations in the memory unit. The memory unit may comprise a physical device utilised to store data or programs, i.e., sequences of instructions, on a temporary or permanent basis. According to some embodiments, the memory unit may comprise integrated circuits comprising silicon-based transistors. The memory unit may comprise e.g. a memory card, a flash memory, a USB memory, a hard disc, or another similar volatile or non-volatile storage unit for storing data such as e.g. ROM (Read-Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable PROM), EEPROM (Electrically Erasable PROM), etc. in different embodiments.

The control arrangement 20 is connected to components of the internal 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 20. These signals may then be supplied to the calculation unit. One or more output signal sending devices may be arranged to convert calculation results from the calculation unit to output signals for conveying to other parts of the vehicle's control system and/or the component or components for which the signals are intended. Each of the connections to the respective components of the internal 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.

In the embodiments illustrated, the internal combustion engine 1 comprises a control arrangement 20 but might alternatively be implemented wholly or partly in two or more control arrangements or control units.

5 Control systems in modern vehicles generally comprise a communication bus system consisting of one or more communication buses for connecting a number of electronic control units (ECUs), or controllers, to various components on board the vehicle. Such a control system may comprise a large number of control units and taking care of a specific function may be shared between two or more of them. Vehicles of the type here concerned are
10 therefore often provided with significantly more control units than depicted in Fig. 1, as one skilled in the art will surely appreciate.

The computer program product 200 may be provided for instance in the form of a data carrier carrying computer program code for performing at least some of the method steps 110, 120,
15 130, 132, 133, 134, 140, 142, 143, and 144 according to some embodiments when being loaded into one or more calculation units of the control arrangement 20. The data carrier may be, e.g. a CD ROM disc, as is illustrated in Fig. 6, or a ROM (read-only memory), a PROM (programmable read-only memory), an EPROM (erasable PROM), a flash memory, an EEPROM (electrically erasable PROM), a hard disc, a memory stick, an optical storage
20 device, a magnetic storage device or any other appropriate medium such as a disk or tape that may hold machine readable data in a non-transitory manner. The computer program product may furthermore be provided as computer program code on a server and may be downloaded to the control arrangement 20 remotely, e.g., over an Internet or an intranet connection, or via other wired or wireless communication systems.

25 It is to be understood that the foregoing is illustrative of various example embodiments and that the invention is defined only by the appended 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
30 herein, without departing from the scope of the present invention, as defined by the appended claims. For instance, the term "air" as used herein may comprise a mixture of air, fuel, and/or recirculated exhaust gases. Further, the terms compression stroke 41, expansion stroke 42, exhaust stroke 43 and inlet stroke 44 may be replaced by the terms compression phase 41, expansion phase 42, exhaust phase 43 and inlet phase 44.

35 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 controlling an internal combustion engine (1), wherein the combustion engine (1) comprises:
 - a valve control arrangement (3, 5) capable of controlling the overlap (O) between inlet valves (7) and outlet valves (9) of the combustion engine (1), and
 - a knock sensing arrangement (11) configured to sense the occurrence of knock in at least one cylinder (13) of the combustion engine (1),wherein the method (100) comprises:
 - determining (110) a knock level (kl) in the at least one cylinder (13),
 - setting (120) an overlap limit (Olim) based on a current overlap (O) used when the determined knock level (kl) exceeds a threshold value (th), and
 - controlling (130) the overlap (O) based on the overlap limit (Olim).
2. The method (100) according to claim 1, wherein the step of controlling (130) the overlap (O) comprises the steps of:
 - setting (132) an overlap target value (Ot) based on the overlap limit (Olim), and
 - controlling (134) the overlap (O) towards the overlap target value (Ot).
3. The method (100) according to claim 2, wherein the step of setting (132) the overlap target value (Ot) comprises the step of:
 - setting (133) the overlap target value (Ot) to a value being offset from the overlap limit (Olim).
4. The method (100) according to claim 2 or 3, wherein the overlap target value (Ot) involves a greater overlap (O) than at the overlap limit (Olim).
5. The method (100) according to any one of the preceding claims, wherein the method (100) further comprises:
 - updating (140) the overlap limit (Olim) by reducing the overlap (O).
6. The method (100) according to claim 5, wherein the method (100) comprises:
 - updating (142) the overlap limit (Olim) periodically.
7. The method (100) according to claim 6, wherein the method (100) comprises:
 - updating (143) the overlap limit (Olim) with a first frequency in steady state operating conditions of the combustion engine (1), and

- updating (144) the overlap limit (Olim) with a second frequency in transient operating conditions of the combustion engine (1),
wherein the second frequency is higher than the first frequency.

- 5 8. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method (100) according to any one of the claims 1 – 7.
- 10 9. A computer-readable medium (200) comprising instructions which, when executed by a computer, cause the computer to carry out the method (100) according to any one of the claims 1 – 7.
10. A control arrangement (20) for controlling an internal combustion engine (1), wherein the combustion engine (1) comprises:
- 15 - a valve control arrangement (3, 5) capable of controlling the overlap (O) between inlet valves (7) and outlet valves (9) of the combustion engine (1), and
- a knock sensing arrangement (11) configured to sense the occurrence of knock in at least one cylinder (13) of the combustion engine (1),
wherein the control arrangement (20) is arranged to:
- 20 - determine a knock level (kl) in the at least one cylinder (13),
- set an overlap limit (Olim) based on a current overlap (O) used when the determined knock level (kl) exceeds a threshold value (th), and
- control the overlap (O) based on the overlap limit (Olim).
- 25 11. An internal combustion engine (1) comprising:
- at least one cylinder (13),
- a piston (15) arranged in each cylinder (13),
- at least one inlet valve (7) at each cylinder (13),
- at least one outlet valve (9) at each cylinder (13),
- 30 - a valve control arrangement (3, 5) capable of controlling the overlap (O) between the inlet valves (7) and the outlet valves (9) of the combustion engine (1),
- a knock sensing arrangement (11) configured to sense the occurrence of knock in at least one cylinder (13) of the combustion engine (1), and
- a control arrangement (20),
- 35 wherein the control arrangement (20) is arranged to:
- determine a knock level (kl) in the at least one cylinder (13),

- setting an overlap limit (Olim) based on a current overlap (O) used when the determined knock level (kl) exceeds a threshold value (th), and
- control the overlap (O) based on the overlap limit (Olim).

5 12. The combustion engine (1) according to claim 11, wherein the valve control arrangement (3, 5) comprises:

- an inlet valve phase-shifting device (3) configured to phase-shift control of the at least one inlet valve (7), and
- 10 - an outlet valve phase-shifting device (5) configured to phase-shift control of the at least one outlet valve (9).

13. The combustion engine (1) according to claim 12, wherein the valve control arrangement (3, 5) is configured to control the overlap (O) by phase-shifting control of the at least one inlet valve (7) and the at least one outlet valve (9).

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14. The combustion engine (1) according to any one of the claims 11 - 13, wherein the combustion engine (1) comprises at least one ignition device (17) in each cylinder (13) of the combustion engine (1).

20 15. The combustion engine (1) according to any one of the claims 11 - 14, wherein the combustion engine (1) is specifically adapted to run on a gaseous fuel.

16. The combustion engine (1) according to any one of the claims 11 - 14, wherein the combustion engine (1) is specifically adapted to run on an alcohol based fuel.

25

17. A vehicle (30) comprising a combustion engine (1) according to any one of the claims 11 - 16.

1/3

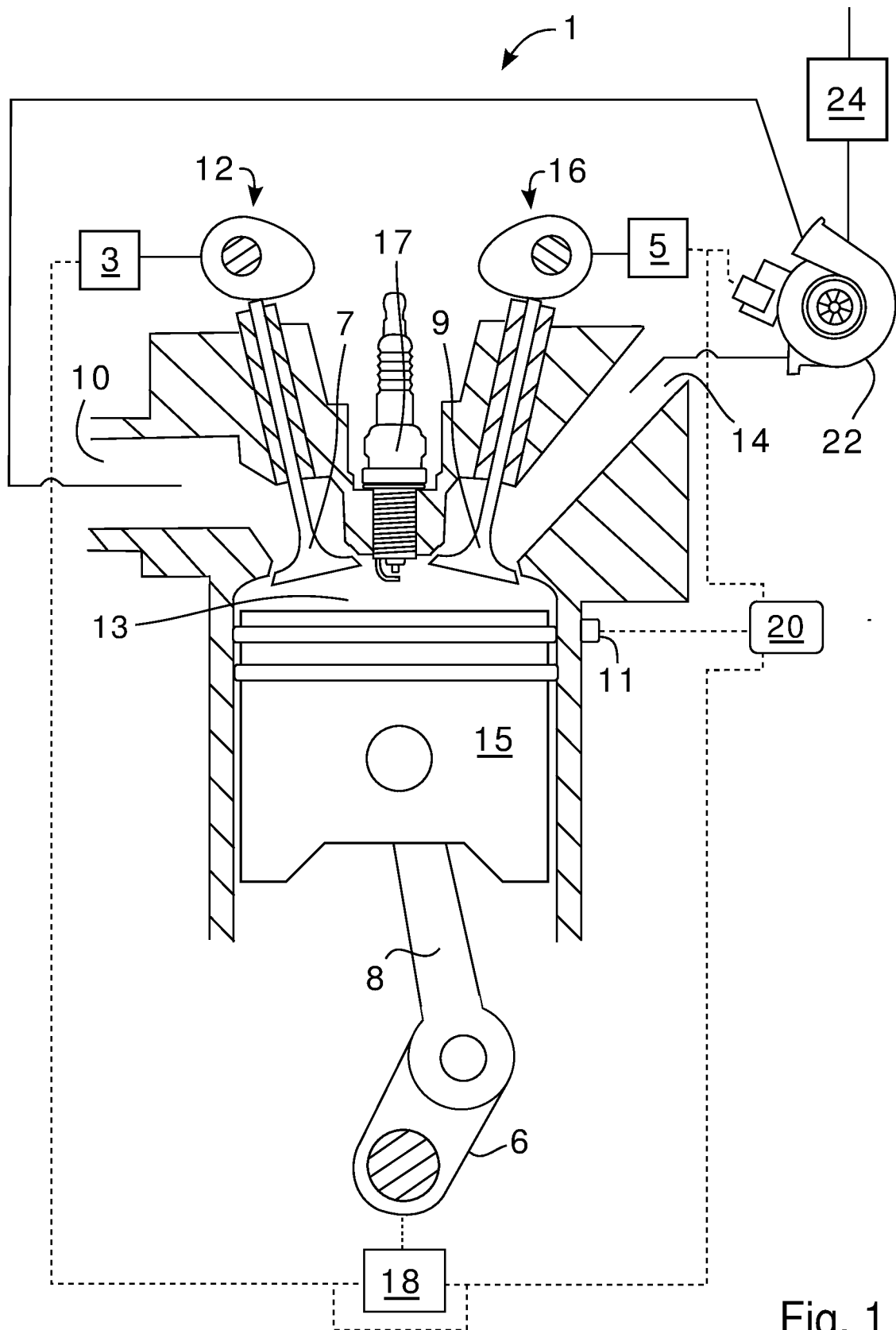


Fig. 1

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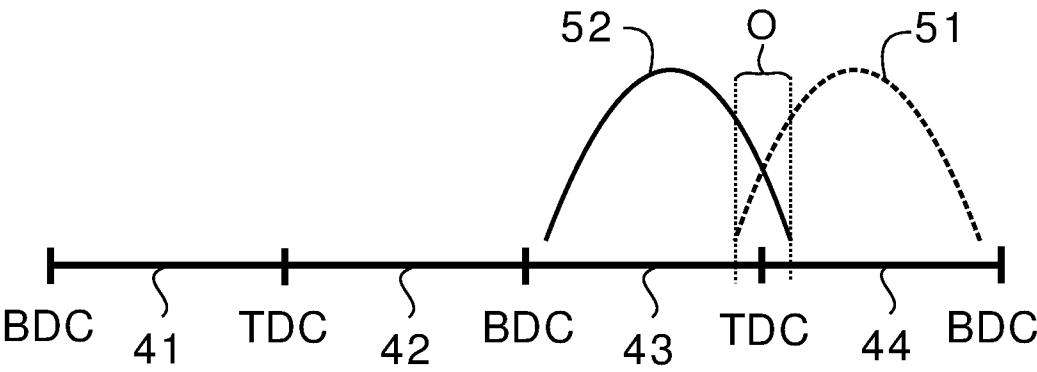


Fig. 2a

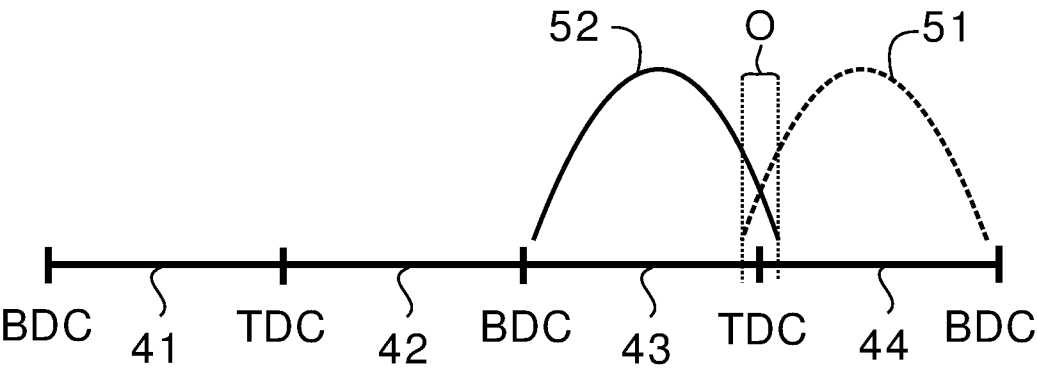


Fig. 2b

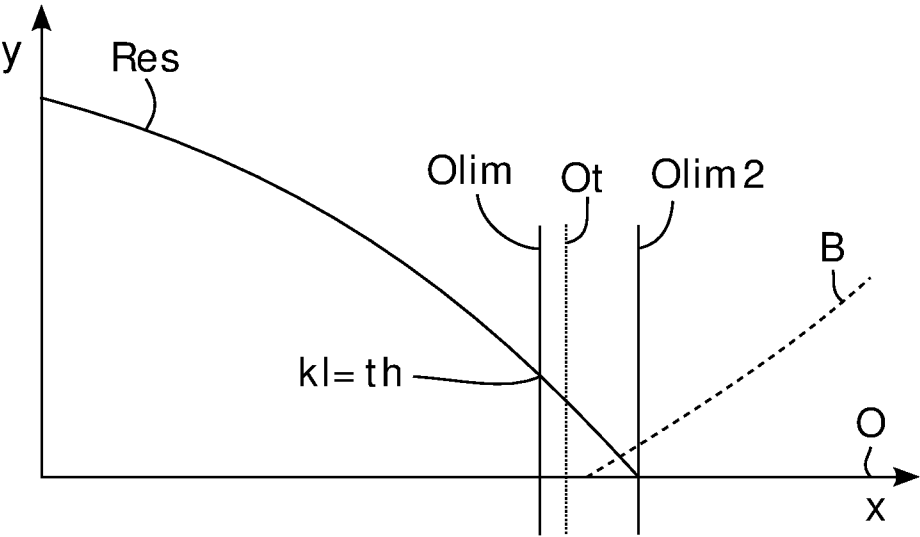


Fig. 3

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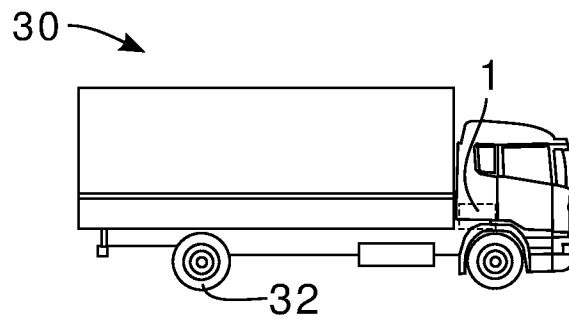


Fig. 4

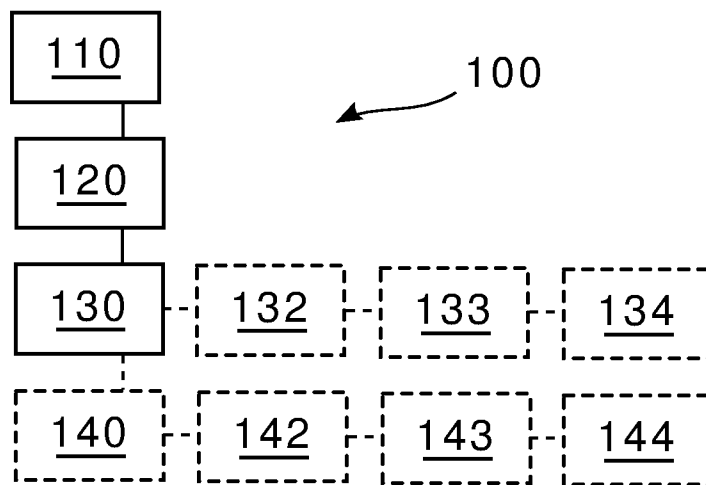


Fig. 5

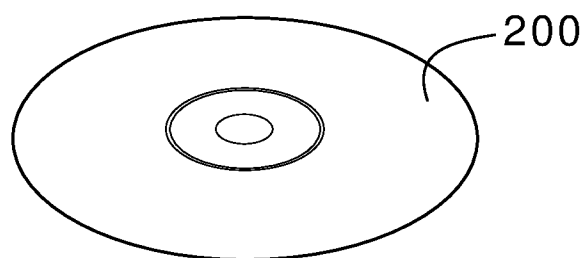


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2020/050066

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D13/02 F02D35/02 F02D41/24
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/050118 A1 (DELP MATTHIAS [DE] ET AL) 26 February 2009 (2009-02-26) paragraphs [0010], [0021], [0024] -----	1-17
X	US 2004/149263 A1 (TANEI KATSUTOSHI [JP] ET AL) 5 August 2004 (2004-08-05) paragraphs [0013] - [0018] -----	1-4,8-17
A	JP H07 26993 A (MAZDA MOTOR) 27 January 1995 (1995-01-27) paragraph [0042] -----	1-17
A	US 2018/051622 A1 (LIU JIM [CN] ET AL) 22 February 2018 (2018-02-22) paragraph [0022] -----	1-17
A	US 2005/005908 A1 (TANEI KATSUTOSHI [JP] ET AL) 13 January 2005 (2005-01-13) paragraphs [0140] - [0142] -----	1-17



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

31 March 2020

Date of mailing of the international search report

06/04/2020

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Le Bihan, Thomas

INTERNATIONAL SEARCH REPORT

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