



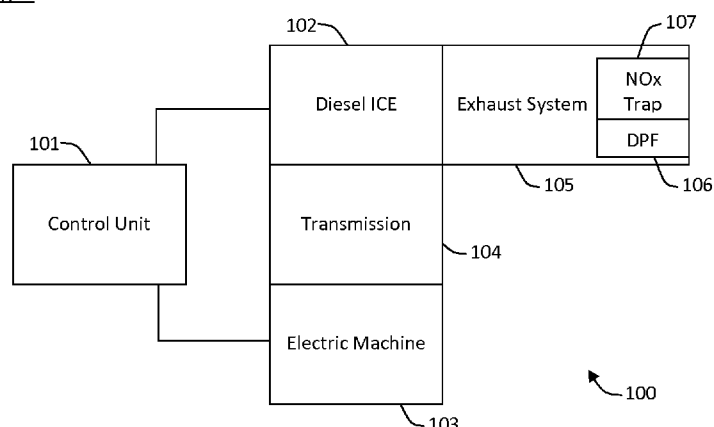
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(54) **Title:** EXHAUST AFTER-TREATMENT SYSTEMFig. 1

(57) **Abstract:** A method of conditioning an exhaust after-treatment system (106, 107), the method comprising providing a power unit. The power unit comprises: an internal combustion engine (102) which produces exhaust; and an exhaust after-treatment system (106, 107). The power unit is arranged to provide a requested torque to a transmission (104), the power unit being further arranged to operate in a first mode and a second mode, such that the power unit provides the requested torque to the transmission in the first mode and the second mode. The exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level. The method further comprises: determining that the exhaust after-treatment system needs to be conditioned; and entering a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

Exhaust After-Treatment System

TECHNICAL FIELD

This invention relates to a method of conditioning an exhaust after treatment system, a power unit comprising an exhaust after-treatment system, a vehicle comprising the same, or a control unit for controlling a power unit.

BACKGROUND

Internal combustion engines generate useful work by igniting a fuel such as diesel or petrol.

An inevitable consequence of the ignition of the fuel is the production of waste products, which are typically expelled from the engine in the form of an exhaust, a mixture of gasses and particulates.

The gasses and particulates produced in an exhaust can be damaging to the environment.

In order to reduce any damage, it is often desirable to treat the exhaust in order to either reduce or change the nature of the particulates or gasses. Such treatments are carried out by an exhaust after-treatment system. An example of an exhaust after treatment system is the Diesel Particulate Filter (DPF) which is often fitted to the exhaust systems of diesel vehicles. The DPF comprises a filter which retains particulates, predominantly soot with some ash as a by-product of oil consumption, from the exhaust gas, so that the particulates are not pumped into the air outside the vehicle with the rest of the exhaust. Other exhaust after-treatment systems include Gasoline Particulate Filters, Lean-NO_x Traps and Selective Catalytic Reduction systems.

During use, a DPF will gradually fill with particulates. In order to prevent the DPF becoming blocked, it is necessary to clear the particulates from the filter periodically. This can be done by manually cleaning or even replacing the filter. Another way to clear particulates from the filter is to encourage the particulates to combust by exposing them to heat and oxygen. This is known as regeneration. The oxidation or further combustion of the particulates causes them to break down so that they can be expelled from the exhaust, clearing the DPF effectively without releasing large particulates into the atmosphere. This approach is advantageous since it allows the DPF to be cleared without a manual intervention, as would be required to replace or manually clean the DPF. The US patent application with publication number 2011/0257821 describes such a method for regenerating a diesel particulate filter in a hybrid engine.

The DPF can be exposed to high temperatures and oxygen levels while the diesel vehicle is being driven. However, maintaining a high enough temperature and oxygen level for a long enough time for the DPF to be cleared places restrictions on the activity of the engine, which can impede performance from the perspective of a driver. Alternatively, if the engine remains completely responsive to the driver this can prolong the regeneration, which typically increases fuel consumption of the vehicle. Therefore it is desirable to be able to clear the DPF quickly while still maximising the performance and responsiveness of the engine.

SUMMARY OF THE INVENTION

In accordance with an aspect of the invention there is provided a method of conditioning an exhaust after-treatment system, the method comprising providing a power unit. The power unit comprises: an internal combustion engine which produces exhaust; and an exhaust after-treatment system. The power unit is arranged to provide a requested torque to a transmission, the power unit being further arranged to operate in a first mode and a second mode, such that the power unit provides the requested torque to the transmission in the first mode and the second mode. The exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level. The method further comprises: determining that the exhaust after-treatment system needs to be conditioned; and entering a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

In accordance with an aspect of the invention there is provided a power unit, the power unit comprising: an internal combustion engine which produces exhaust; a control unit; and an exhaust after-treatment system. The control unit is arranged to control the power unit to provide a requested torque to a transmission, the control unit being further arranged to operate the power unit in a first mode and a second mode, such that the power unit provides the requested torque to the transmission in the first mode and the second mode. The exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level. The control unit is further arranged to: determine that the exhaust after-treatment system needs to be conditioned; and cause the power unit to enter a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

In these ways the invention provides for conditioning the exhaust after-treatment system of a power unit while minimising the disruption to the operation of the power unit. The first mode can be chosen such that the first characteristic in the first mode is well suited to conditioning the after-treatment system of the power unit, for example by encouraging combustion of particulates in a filter. The second mode, meanwhile, can be chosen such that the vehicle remains more responsive to the driver.

The power unit is a unit comprising at least one device which is capable of converting stored energy into kinetic motion, such as an internal combustion engine or an electric machine. A power unit may further comprise other components such as a transmission. Colloquially, a power unit may be known as an engine.

Conditioning the exhaust after-treatment system typically comprises changing the state of the exhaust after-treatment system.

Typically, the power unit is in a third mode when the control unit determines that the exhaust after-treatment system needs to be conditioned. The first characteristic may be at a fifth level when the power unit is in the third mode. The power unit may return to the third mode when the control unit determines that the exhaust after-treatment system has been sufficiently conditioned. Alternatively, the power unit may return to a fourth mode when the control unit determines that the exhaust after-treatment system has been sufficiently conditioned, if the control unit determines that a different mode is preferable. The first characteristic may be at a sixth level when the power unit is in the fourth mode.

The power unit may be a hybrid power unit, a diesel power unit, a petrol or gasoline power unit, or any other type of power unit which produces an exhaust. Where the power unit is a hybrid power unit which may operate in a fuel burning mode and a non-fuel burning mode, the non-fuel burning mode for example comprising using stored electrical energy in a battery to drive a traction motor, the power unit will operate in a fuel burning mode when in the first mode or the second mode. The power unit may operate in a fuel burning mode or a non-fuel burning mode when in the third mode.

In the cyclical mode the power unit enters the first mode and the second mode at least twice each. In the cyclical mode the power unit typically alternates between the first and second modes, entering at least first mode, then second mode, then first mode, then second mode again. The cyclical mode may comprise the power unit entering other modes in addition to the first and second modes. For example, the cyclical mode may comprise entering a first

mode, then a second mode, and then a third mode before returning to the first mode and then the second mode again. The cyclical mode may comprise as many modes as are necessary.

- 5 The transmission typically comprises a connecting member which transmits torque from the power unit to further components, such as wheels. The transmission may further comprise a gear box.

- 10 Where there is an operator such as a driver in charge of the power unit, the requested torque is typically a torque requested by the operator. Alternatively, the requested torque may be requested by an automated system such as a cruise control.

- 15 Typically, the first characteristic is the temperature of the exhaust gas. Alternatively, the first characteristic may be a measure of any other suitable characteristic of the exhaust, such as the oxygen content of the exhaust, or the un-combusted fuel content of the exhaust.

- It may be that the exhaust produced by the fuel burning motor possesses a second characteristic, such that in the first mode the second characteristic is at a third level and in the second mode the second characteristic is at a fourth level.

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Typically, the second characteristic is the oxygen content of the exhaust gas. The oxygen content of the exhaust gas may be measured as a percentage of the total volume of the exhaust gas or as a percentage of the total mass of the exhaust gas.

- 25 Where the first characteristic is the temperature of the exhaust gas, it may be that the temperature of the exhaust gas is substantially higher in the first mode than in the second mode, and it may be that in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

- 30 Where the second characteristic is the oxygen content of the exhaust gas, it may be that the oxygen content of the exhaust gas is substantially higher in the second mode than in the first mode, and it may be that in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

- 35 The first and second characteristics may be chosen to complement each other. For example, where the first characteristic is temperature and the second characteristic is oxygen, it may be that the first and second modes are chosen such that, in the first mode the temperature of

the exhaust is higher than in the second mode, and in the second mode the oxygen content of the exhaust is higher than in the first mode. Hence, while the power unit is in the first mode the exhaust after-treatment system is heated by the exhaust. Then, when the power unit switches into the second mode, the increase in oxygen in the already heated exhaust after-treatment system environment encourages the combustion of any particulates which are trapped there. Repeated switching of this type can be used to clear particulates from the exhaust after-treatment system, but since the internal combustion engine need only provide either a high temperature exhaust or high oxygen content exhaust at any given time, this places fewer restrictions on the power unit than would be the case where it necessary to provide an exhaust emission which is both high temperature and high in oxygen content simultaneously.

An internal combustion engine is one which burns a fuel such as diesel, petrol or gas (such as liquefied petroleum gas) and directly translates the energy produced by the combustion into mechanical motion within a combustion chamber. The internal combustion engine is typically a reciprocating or piston engine, but may be any other sort of internal combustion engine such as a gas turbine engine.

Typically, the internal combustion engine is a diesel engine. It may be that the exhaust after treatment system comprises a diesel particulate filter.

It may be that the internal combustion engine is a petrol or gasoline engine. It may be that the exhaust after treatment system comprises a gasoline particulate filter.

In some embodiments, the power unit further comprises an electric machine, the internal combustion engine and the electric machine being arranged to cooperate in providing the requested torque to the transmission,

the electric machine being arranged to:

provide a first percentage of the torque in the first mode; and

provide a second percentage of the torque in the second mode,

wherein the first percentage of the torque is substantially different from the second percentage.

Typically, the first percentage is lower than the second percentage. The power unit may comprise a plurality of electric machines which are arranged to provide the requested torque to the transmission. Typically, the total torque provided to the transmission by all internal combustion engines and electric machines in the power unit will be the requested torque, the

requested torque being set by a user. Typically, the total torque provided to the transmission by all internal combustion engines and electric machines in the power unit remains constant while in a cyclical mode, unless the user changes the requested torque, for example by operating a throttle.

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Varying the amount of torque produced by the internal combustion engine in this way can change the composition of the exhaust produced.

10 An aspect of the invention provides a vehicle, such as a car, truck or boat, which comprises a power unit as described above. Alternately, a power unit as described above could be used in a generator, or any other application where torque is required.

An aspect of the invention provides a control unit suitable for use in controlling a power unit, the control unit being arranged to carry out the method as described above.

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BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

Figure 1 shows a block diagram of a first power unit;

20 Figure 2 is a graph showing the torque produced by an Internal combustion engine (ICE) and an electric machine in the first power unit when the first power unit is in a cleaning mode;

Figure 3 is a graph showing the temperature of the first power unit while it is in a cleaning mode;

25 Figure 4 is a graph showing the progression of cleaning in the first power unit, contrasted with the progression of cleaning in a similar power unit which is cleaned according to the prior art; and

Figure 5 is a graph showing the torque produced by an ICE and an electric machine in the first power unit when the first power unit is in a cleaning mode.

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DETAILED DESCRIPTION

Figure 1 shows a block diagram of a first power unit 100 from a vehicle according to the invention. The first power unit 100 is a hybrid power unit and comprises a control unit 101, which controls the operation of a diesel internal combustion engine (ICE) 102 and an electric machine 103. The diesel ICE 102 burns diesel fuel in order to produce torque and an exhaust which primarily comprises heated gasses and particulates. The electric machine 103 draws charge from a battery (not shown) and also produces torque. Both the diesel ICE

102 and the electric machine 103 are connected to a transmission 104 which is in turn connected to the wheels of the vehicle (not shown) such that the diesel ICE 102 and the electric machine 103 can be used to drive the vehicle.

- 5 The diesel ICE 102 is connected to an exhaust system 105 which comprises a Diesel Particulate Filter (DPF) 106 and a NOx trap 107. The DPF 106 captures large particulates of incompletely combusted fuel which are expelled with the exhaust, in order to prevent them passing on into the environment through the exhaust system 105. Over time, the DPF 106 can become clogged with particulates. Hence, the control unit 101 is arranged to cause the
10 first power unit 100 to enter a first cleaning mode periodically.

Figure 2 is a graph showing the behaviour of the diesel ICE 102 and the electric machine 103 when the first power unit 100 is in a first cleaning mode. The torque exerted on the transmission 104 by the diesel ICE 102 is indicated by the solid line 201. The torque exerted
15 on the transmission 104 by the electric machine 103 is indicated by the dashed line 202. The torque requested by the driver is indicated by the dotted line 203. At a time t_0 , the vehicle is driving forwards and the first power unit 100 is not yet in a first cleaning mode. Rather, the first power unit 100 is in a diesel driving mode in which the diesel ICE 102 is exerting a torque T_1 on the transmission 104 in order to maintain a forward momentum in the vehicle
20 and the electric machine 103 is turned off so that it exerts no torque on the transmission 104. The torque T_1 is a torque that is requested by a driver of the vehicle.

At a time t_1 , the first power unit 100 enters the first cleaning mode. The first cleaning mode comprises a first mode and a second mode, and the control unit 101 is arranged to alternate
25 between the first mode and the second mode while in the first cleaning mode. Between t_1 and t_2 , the first power unit is in the first mode, in which the control unit 101 drives the diesel ICE 102 to provide a torque T_2 to the transmission 104. T_2 is greater than T_1 . To counterbalance the additional torque from the diesel ICE 102, the control unit activates the electric machine 103. The electric machine 103 is driven to exert a torque T_3 on the
30 transmission 104, where T_3 is a negative torque such that it resists the forward motion of the vehicle, and such that:

$$T_1 = T_2 + T_3$$

35 Hence the total torque exerted on the transmission by the diesel ICE 102 and the electric machine 103 is still T_1 between t_1 and t_2 .

Between t_2 and t_3 , the first power unit is in the second mode, in which the control unit 101 drives the diesel ICE 102 to provide a torque T_4 to the transmission 104. T_4 is less than T_2 and, in this example, less than T_1 . To counterbalance the reduced torque from the diesel ICE 102, the control unit drives the electric machine 103 to exert a torque T_5 on the transmission 104, where T_5 is chosen such that:

$$T_1 = T_4 + T_5$$

Hence the total torque exerted on the transmission by the diesel ICE 102 and the electric machine 103 is still T_1 between t_2 and t_3 .

At t_3 , the control unit causes the first power unit 100 to return to the first mode again. The first power unit alternates between the first and second modes until at t_7 the control unit 101 causes the first power unit 100 to leave the first cleaning mode and return to the diesel driven mode in which the electric machine 103 is again deactivated and the diesel ICE 102 is driven to produce a torque of T_1 . The diesel driven mode therefore constitutes a third mode, which the power unit is in before entering the first cleaning mode, and which the power unit returns to after leaving the first cleaning mode. Alternatively, if the driving conditions have changed, the control unit 101 may determine that the first power unit 100 should return to a fourth mode instead of the diesel driven mode. The fourth mode might, for example, be an electric mode in which the electric machine 103 is driven to provide torque to the transmission 104, and the diesel ICE 102 is deactivated.

Figure 3 shows the change in temperature of the DPF 106 during the time period in which the first power unit 100 is driven in a first cleaning mode by the control unit 101, as indicated by line 301.

Initially, the temperature of the DPF 106 is constant at x_1 . However, when the first power unit 100 enters the first mode between t_1 and t_2 , the increased workload of the diesel ICE 102 creates a hotter exhaust, which in turn increases the temperature of the DPF 106. When the first power unit 100 enters the second mode, for example between t_2 and t_3 , the workload of the diesel ICE 102 drops, which causes the exhaust temperature to drop. Hence the temperature of the DPF 106 also drops between t_2 and t_3 . However, as can be seen from the graph, since the first power unit 100 spends longer in the first mode than in the second mode, the temperature of the DPF 106 rises overall while the first power unit is in a first cleaning mode between t_1 and t_7 .

While the first power unit 100 is in the second mode, the control unit 101 is arranged to drive the diesel ICE 102 such that the oxygen content in the exhaust is higher than when the first power unit 100 is in the first mode. Depending upon the design of the diesel ICE 102, this may result naturally from operating the diesel ICE 102 to produce a lower torque.

Alternatively, this may be achieved by adjusting the operation of the diesel ICE 102, for example by allowing more air into the combustion chamber, so that more oxygen is left when the fuel in the chamber has combusted.

Hence, when the first power unit 100 is in the second mode the DPF 106 is both hot, due to residual heat from the first mode, and supplied with oxygen. This combination of factors encourages any particulates in the DPF 106 to combust. The effect is analogous to opening a door in a burning building, which allows oxygen into a heated room so that the fire in the room “flashes” and consumes much of the fuel in the room. In the same way, much of the particulates caught in the DPF 106 are burnt and hence broken down while the first power unit 100 is in the second mode. By repeatedly cycling between the first and second modes, the temperature of the DPF 106 continues to rise as is shown in Figure 3, such that more of the particulates are consumed.

The power unit requires some time to heat up. Hence the control unit is arranged to put the power unit into the first mode for a few minutes during any given cycle between the first mode and the second mode. However it is not necessary to keep the power unit in the second mode for a long period of time; the control unit is arranged to put the power unit into the second mode for only a few seconds during any given cycle. Typically, the control unit will put the power unit into a first mode for between one and three minutes, before putting the power unit into the second mode for between five and ten seconds. These lengths of time may vary depending upon the configuration of the first power unit 100 and the driving conditions, and the control unit can be arranged to take this into account.

Figure 4 shows the progress of the regeneration of the DPF 106 while the first power unit 100 is in the first cleaning mode as line 401. Line 402 shows the progress of a similar power unit in which a DPF is cleaned using a more conventional method which attempts to provide both heat and oxygen to the DPF simultaneously. As can be seen, the method according to the invention is significantly faster.

Figure 5 is a chart showing how the control unit 101 responds to a change in the requested torque during a regeneration. The torque exerted on the transmission 104 by the diesel ICE 102 is indicated by the solid line 501. The torque exerted on the transmission 104 by the

electric machine 103 is indicated by the dashed line 502. The torque requested by the driver is indicated by the dotted line 503. As can be seen on the dotted line 503, the driver changes the requested torque from T_1 to T_6 at a time t_3' . Before t_3' , the power unit operates identically to the scenario shown in Figure 2. At t_3' , the driver requests a reduction in the torque being applied to the transmission 104. The control unit 101 accommodates this request by reducing the torque provided by the electric machine 103 while keeping the torque provided by the diesel ICE 102 at the levels required to regenerate the DPF 106. The torque provided by the electric machine 103 is reduced in both the first mode and the second mode such that the total torque provided is consistently T_6 . In this way the first power unit 100 can respond dynamically to changing requests for torque made by the driver.

The first power unit 100 further comprises a NOx trap 107. The NOx trap absorbs NO and NO₂ from the exhaust during the normal operation of the vehicle. Over time, the NOx trap becomes saturated with NO and NO₂ such that it stops absorbing these gasses and they are released into the atmosphere. A NOx trap can be purged by introducing a reactant, such as uncombusted diesel fuel, into the NOx trap. The reactant reacts with the NO and NO₂ to produce less damaging exhaust products such as water and nitrogen gas which can safely be released into the atmosphere.

The first power unit 100 can enter into a fifth mode in which diesel fuel is injected into the combustion chamber at a late stage in the combustion cycle. This diesel is not combusted in the combustion chamber, and is instead drawn with the exhaust from the combustion chamber through the exhaust system 105 to the NOx trap 107.

In order to regenerate the NOx trap 107, the control unit 101 enters into a second cleaning mode. In the second cleaning mode the control unit causes the power unit to alternate between the third mode and the fifth mode. In the fifth mode diesel is introduced to the NOx trap 107, regenerating the trap. In the third mode the first power unit 100 is more responsive to the driver's requirements.

The embodiment described above describes a first power unit 100 which comprises a diesel ICE 102 and a DPF 106. However the invention can also be applied to other power units. In one embodiment, a regeneration method as described above is used to clear the filter in a hybrid power unit which comprises a gasoline internal combustion engine and a gasoline particulate filter. Methods and systems according to the invention can also be used to regenerate or condition other exhaust after-treatment systems such as selective catalytic reduction systems.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of them mean “including but not limited to”, and they are not intended to (and do not) exclude other moieties, additives, components, integers or steps.

- 5 Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.
- 10 Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or
- 15 process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel
- 20 combination, of the steps of any method or process so disclosed.

Further aspects of the present invention are outlined in the following series of numbered paragraphs:

- 25 1. A method of conditioning an exhaust after-treatment system, the method comprising providing a power unit, the power unit comprising: an internal combustion engine which produces exhaust; and an exhaust after-treatment system,
- the power unit being arranged to provide a requested torque to a transmission, the power unit being further arranged to operate in a first mode and a second mode, such that
- 30 the power unit provides the requested torque to the transmission in the first mode and the second mode,
- wherein the exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level,
- 35 the method further comprising:
- determining that the exhaust after-treatment system needs to be conditioned; and

entering a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

5 2. A power unit, the power unit comprising: an internal combustion engine which produces exhaust; a control unit; and an exhaust after-treatment system,

wherein the control unit is arranged to control the power unit to provide a requested torque to a transmission, the control unit being further arranged to operate the power unit in a first mode and a second mode, such that the power unit provides the requested torque to
10 the transmission in the first mode and the second mode,

wherein the exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level,

the control unit being further arranged to:
15 determine that the exhaust after-treatment system needs to be conditioned; and
cause the power unit to enter a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

20 3. A method according to numbered paragraph 1 or power unit according to numbered paragraph 2, wherein the first characteristic is the temperature of the exhaust gas.

4. A method or power unit according to numbered paragraph 3, wherein the temperature of the exhaust gas is substantially higher in the first mode than in the second
25 mode, and wherein in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

5. A method or power unit according to any preceding numbered paragraph, wherein the exhaust produced by the fuel burning motor possesses a second characteristic, and
30 wherein in the first mode the second characteristic is at a third level and in the second mode the second characteristic is at a fourth level.

6. A method or power unit according to numbered paragraph 5, wherein the second characteristic is the oxygen content of the exhaust gas.

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7. A method or power unit according to numbered paragraph 5, wherein the oxygen content of the exhaust gas is substantially higher in the second mode than in the first mode, and wherein in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

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8. A method or power unit according to any preceding numbered paragraph, wherein the internal combustion engine is a diesel engine.

9. A method or power unit according to numbered paragraph 8, wherein the exhaust after treatment system comprises a diesel particulate filter.

10. A method or power unit according to any preceding numbered paragraph, wherein the power unit further comprises an electric machine, the internal combustion engine and the electric machine being arranged to cooperate in providing the requested torque to the transmission, the electric machine being arranged to:

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provide a first percentage of the torque in the first mode; and

provide a second percentage of the torque in the second mode,

wherein the first percentage of the torque is substantially different from the second percentage.

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11. A vehicle comprising a power unit according to any of numbered paragraphs 2 to 10.

12. A control unit according to any of paragraphs 2 to 10, the control unit being suitable for use in controlling a power unit, the power unit being according to any of paragraphs 1 or 3 to 10.

25

CLAIMS

1. A method of conditioning an exhaust after-treatment system, the method comprising
5 providing a power unit, the power unit comprising: an internal combustion engine which produces exhaust; and an exhaust after-treatment system,

the power unit being arranged to provide a requested torque to a transmission, the power unit being further arranged to operate in a first mode and a second mode, such that the power unit provides the requested torque to the transmission in the first mode and the
10 second mode,

wherein the exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level,

the method further comprising:

15 determining that the exhaust after-treatment system needs to be conditioned; and

entering a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

2. A power unit, the power unit comprising: an internal combustion engine which produces exhaust; a control unit; and an exhaust after-treatment system,

wherein the control unit is arranged to control the power unit to provide a requested torque to a transmission, the control unit being further arranged to operate the power unit in a first mode and a second mode, such that the power unit provides the requested torque to
25 the transmission in the first mode and the second mode,

wherein the exhaust produced by the internal combustion engine possesses a first characteristic, and in the first mode the first characteristic is at a first level and in the second mode the first characteristic is at a second level,

the control unit being further arranged to:

30 determine that the exhaust after-treatment system needs to be conditioned; and

cause the power unit to enter a cyclical mode to condition the exhaust after-treatment system, the cyclical mode being one in which the power unit cycles repeatedly between the first mode and the second mode.

3. A method according to claim 1 or power unit according to claim 2, wherein the first characteristic is the temperature of the exhaust gas.

4. A method or power unit according to claim 3, wherein the temperature of the exhaust gas is substantially higher in the first mode than in the second mode, and wherein in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

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5. A method or power unit according to any preceding claim, wherein the exhaust produced by the fuel burning motor possesses a second characteristic, and wherein in the first mode the second characteristic is at a third level and in the second mode the second characteristic is at a fourth level.

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6. A method or power unit according to claim 5, wherein the second characteristic is the oxygen content of the exhaust gas.

7. A method or power unit according to claim 5, wherein the oxygen content of the exhaust gas is substantially higher in the second mode than in the first mode, and wherein in the cyclical mode the power unit spends substantially longer in the first mode than the second mode.

8. A method or power unit according to any preceding claim, wherein the internal combustion engine is a diesel engine.

9. A method or power unit according to claim 8, wherein the exhaust after treatment system comprises a diesel particulate filter.

10. A method or power unit according to any preceding claim, wherein the power unit further comprises an electric machine, the internal combustion engine and the electric machine being arranged to cooperate in providing the requested torque to the transmission, the electric machine being arranged to:

provide a first percentage of the torque in the first mode; and
provide a second percentage of the torque in the second mode,
wherein the first percentage of the torque is substantially different from the second percentage.

11. A vehicle comprising a power unit according to any of claims 2 to 10.

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12. A control unit according to any of claims 2 to 10, the control unit being suitable for use in controlling a power unit, the power unit being according to any of claims 1 or 3 to 10.

13. A method, a power unit or a vehicle substantially as hereinbefore described with reference to the accompanying drawings.

Fig. 1

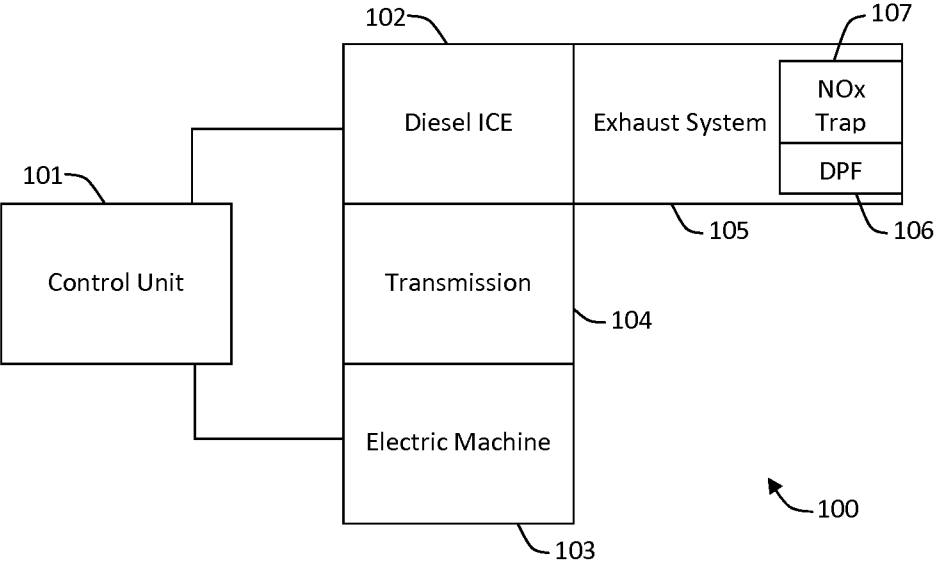


Fig. 2

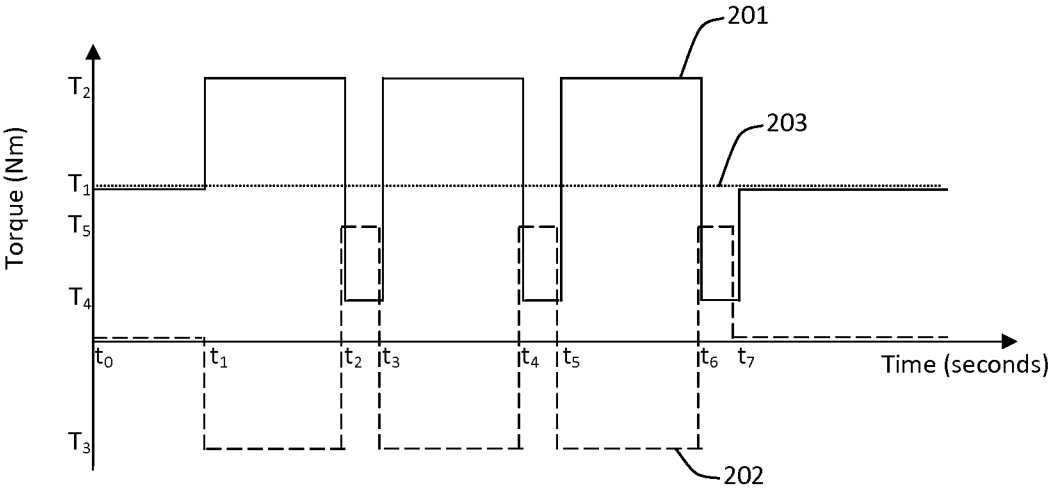


Fig. 3

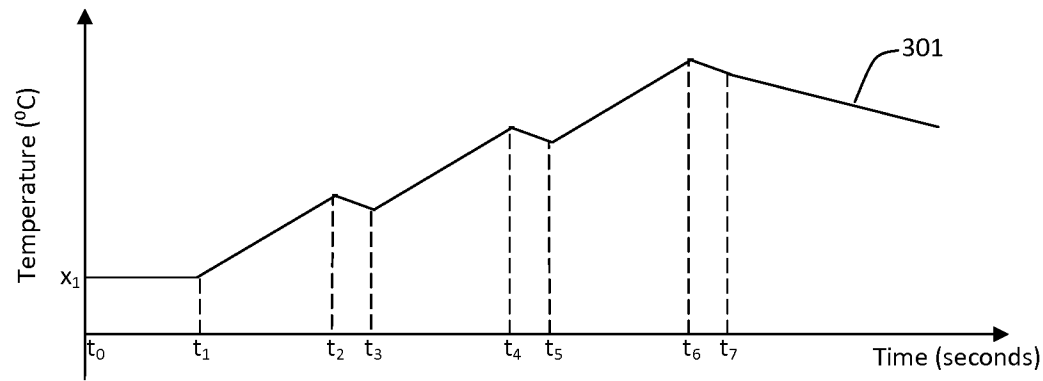


Fig. 4

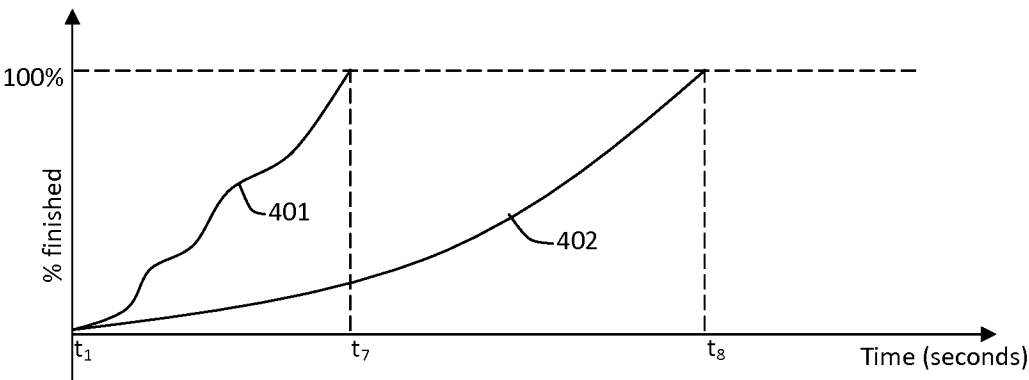
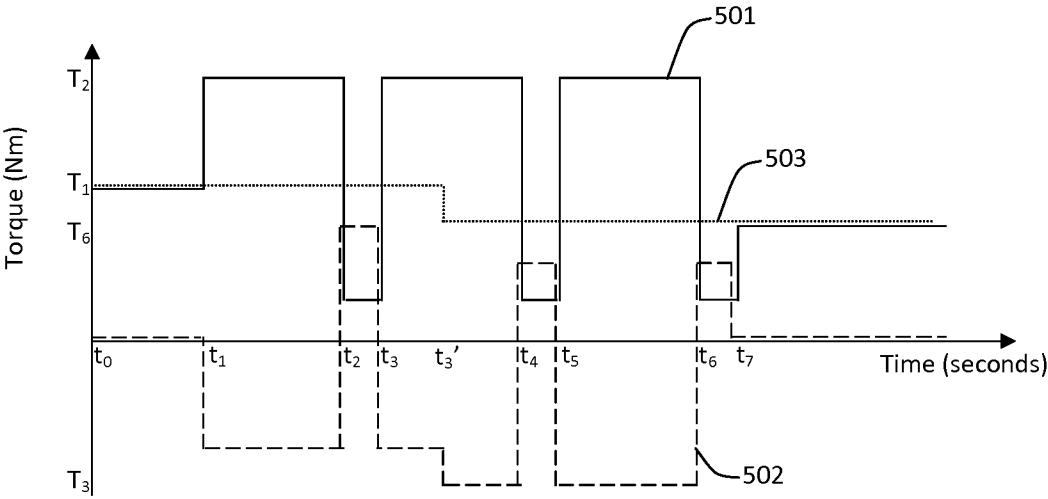


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/067053

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/02 F01N9/00
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 F01N

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

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

EPO-Internal, WPI Data

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X	WO 2014/071961 A1 (VOLVO TRUCK CORP [SE]; LUNDSTEDT BJÖRN [SE]; TÖRNGREN STYRBJÖRN [SE]) 15 May 2014 (2014-05-15) page 2, line 4 - page 11, line 19 page 16, line 20 - page 25, line 24 figures 2,3 ----- -/--	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

9 October 2015

Date of mailing of the international search report

23/10/2015

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/067053

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