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(54) **ENGINE BRAKE METHOD FOR OPERATING A VEHICLE WITH A TURBOCHARGED INTERNAL COMBUSTION ENGINE AND ASSOCIATED VEHICLE**

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F02D 41/00	(2006.01)
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CPC ***F02D 13/04*** (2013.01); ***F02B 37/22*** (2013.01); ***F02D 9/06*** (2013.01); ***F02D 41/0007*** (2013.01); ***F02D 41/1401*** (2013.01)

(58) **Field of Classification Search**

CPC F02D 13/04; F02D 9/06; F02D 41/0007

See application file for complete search history.

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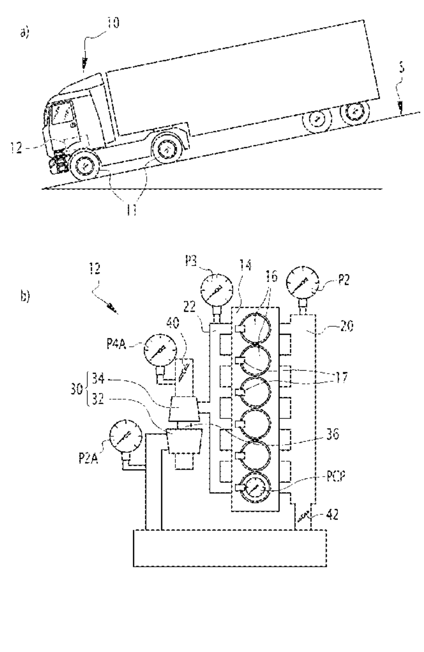
(57) **ABSTRACT**

An engine brake method is for operating a vehicle with a turbocharged internal combustion engine. The engine comprises a boost pressure regulation device, which is configured to adjust the boost pressure in the intake manifold, and an exhaust gas restriction device, which is located downstream from a turbine of the turbocharger and which is configured to regulate an air exhaust pressure in an exhaust manifold. The engine brake method includes a dual phase during which, simultaneously, the boost pressure regulation device regulates the air exhaust pressure in the exhaust manifold in closed loop, and the exhaust gas restriction device controls the boost pressure in closed loop.

7 Claims, 7 Drawing Sheets



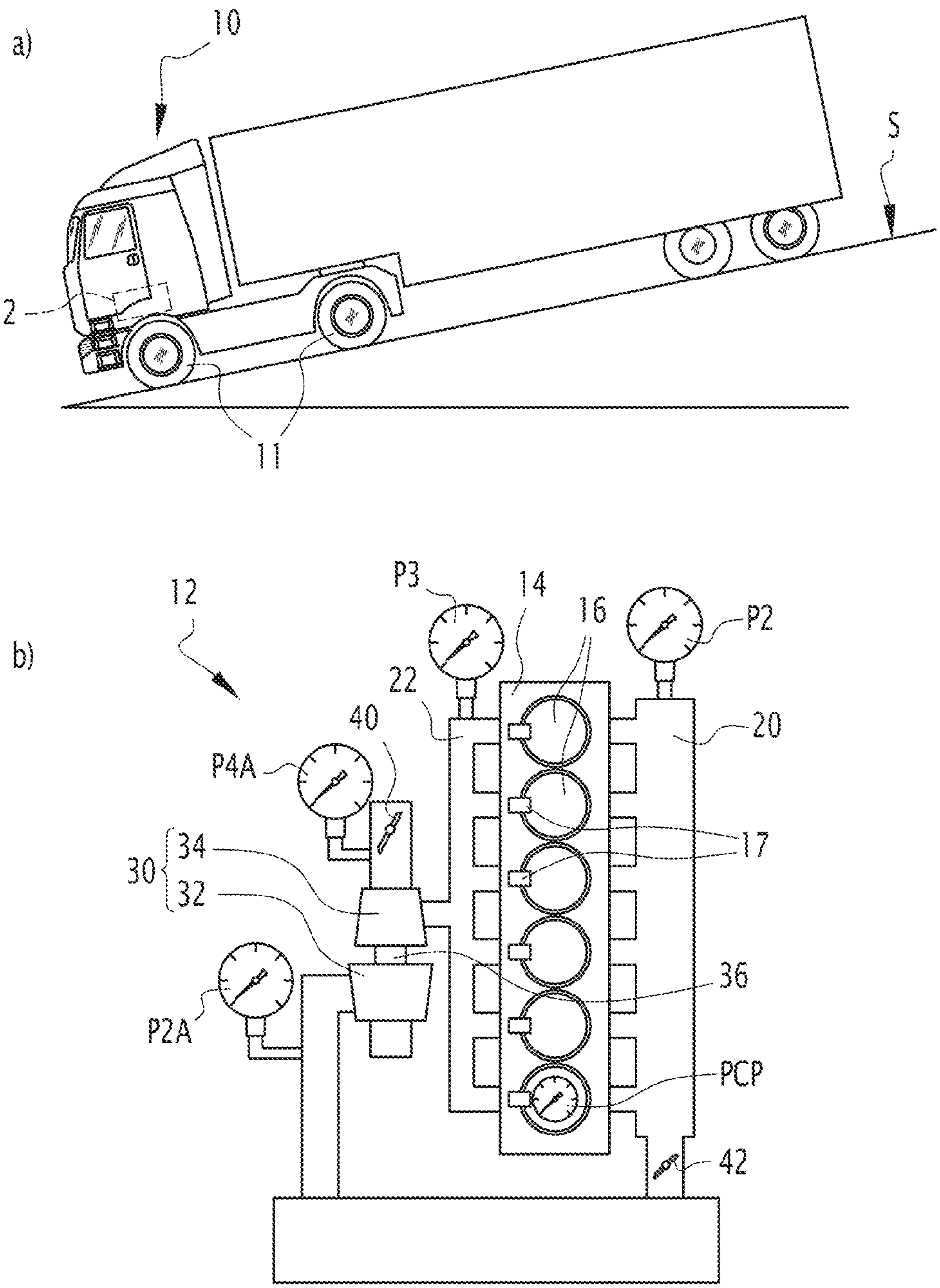


FIG.1

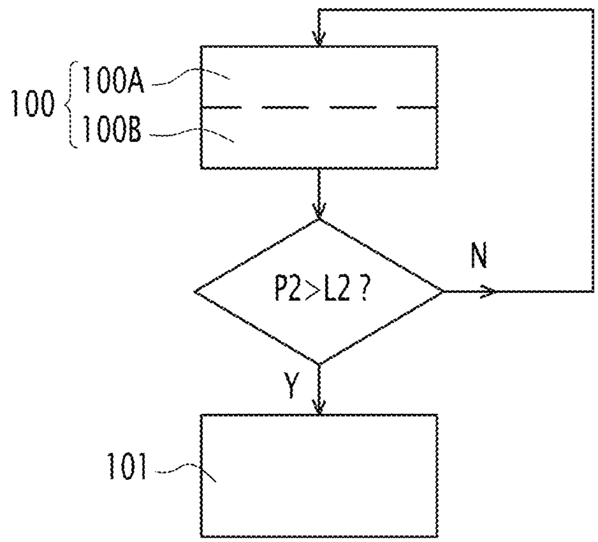


FIG.2

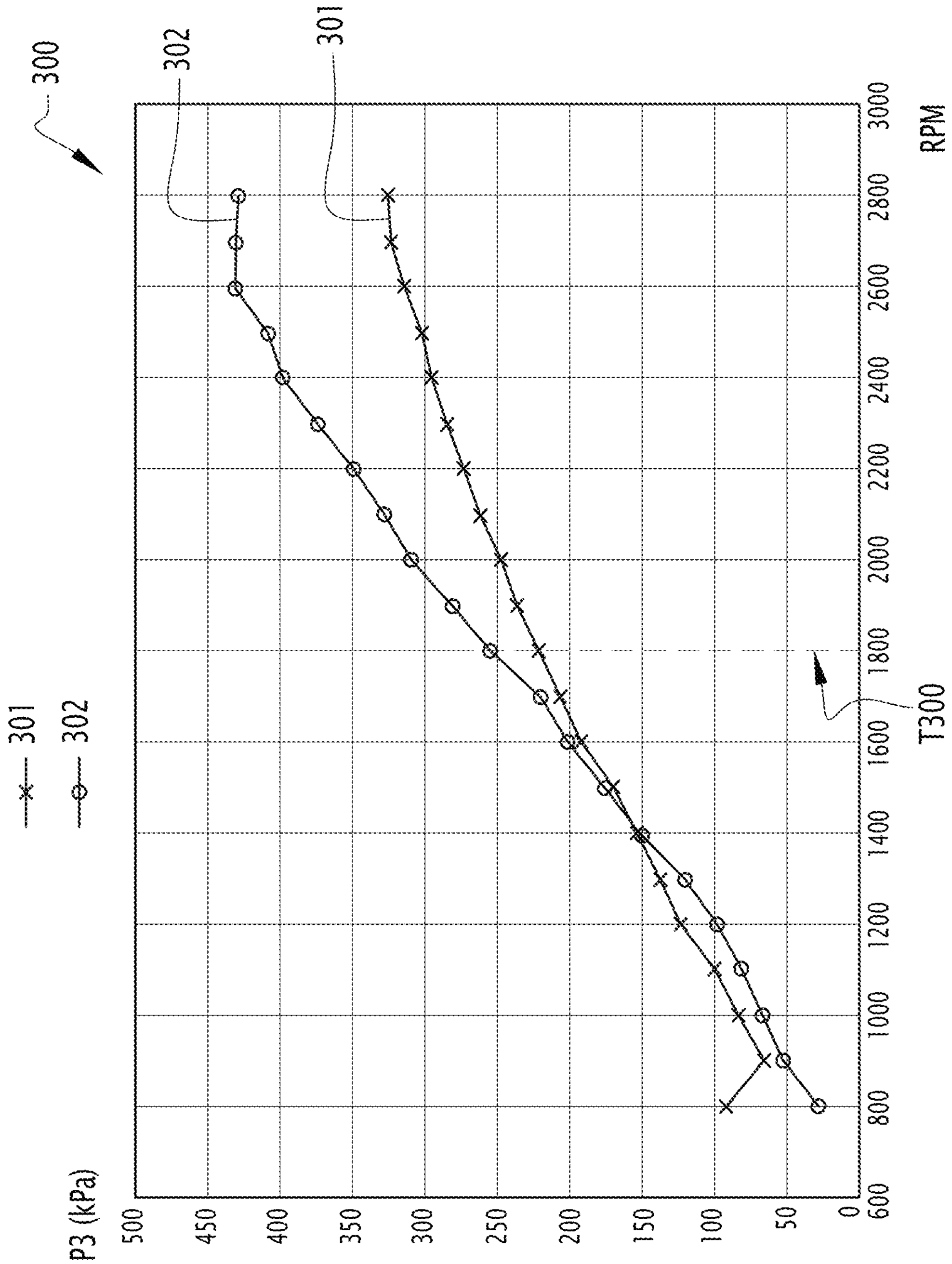

300
301
302
P3 (kPa)
RPM
T300
0
50
100
150
200
250
300
350
400
450
500
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

FIG.3

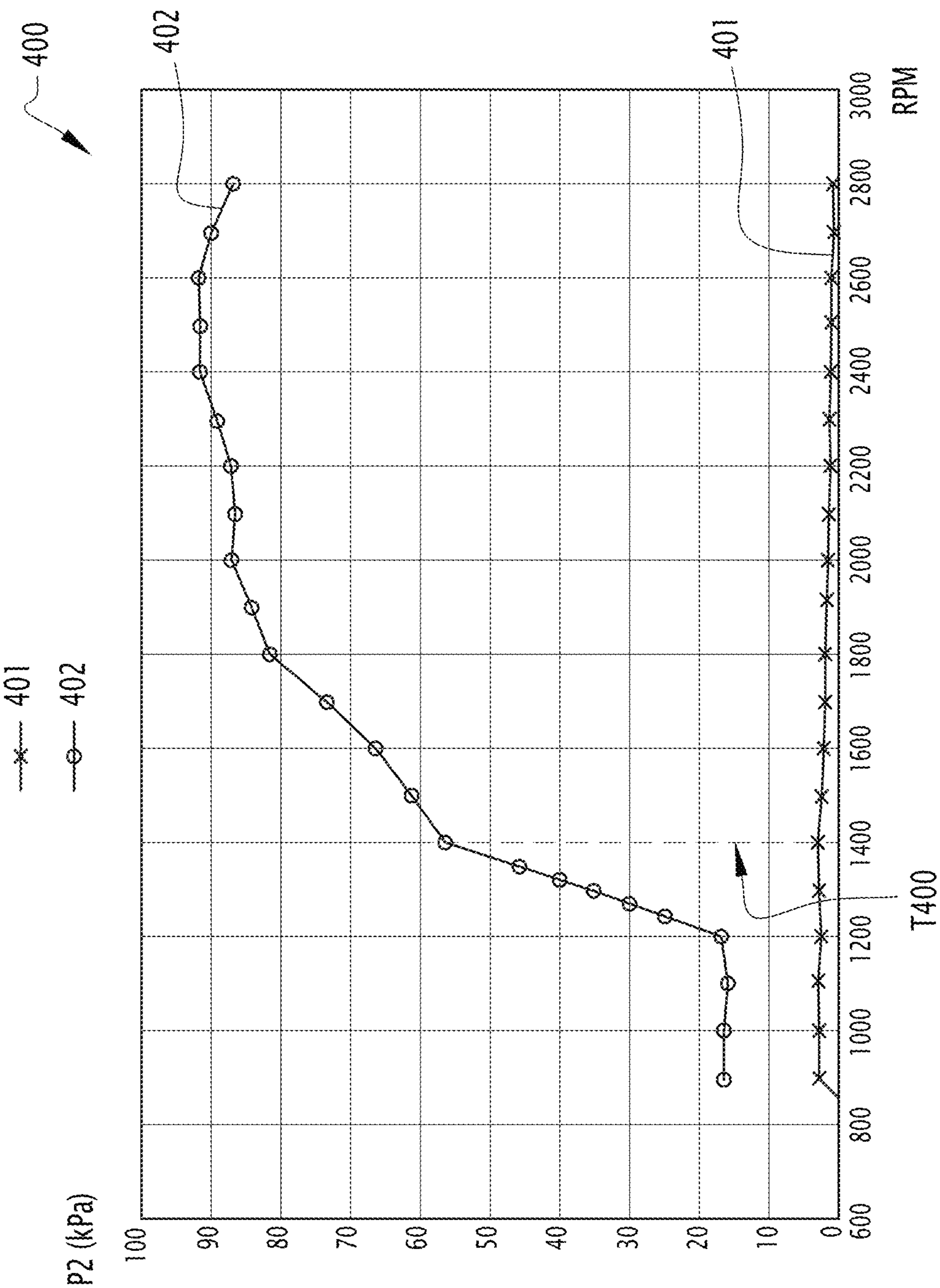

400
401
402
P2 (kPa)
100
90
80
70
60
50
40
30
20
10
0
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
RPM
T400

FIG. 4

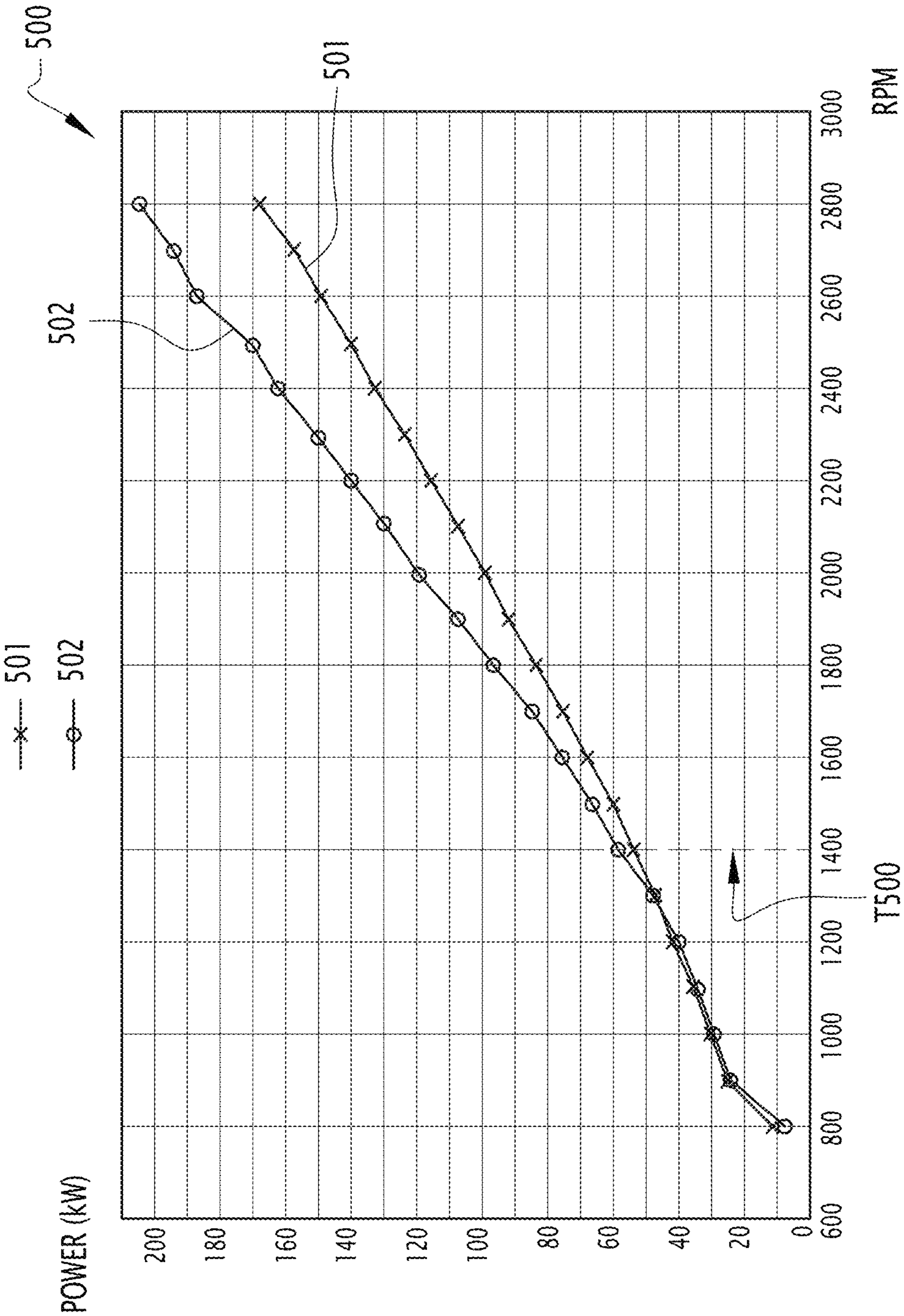

500
501
502
501
502
POWER (kW)
200
180
160
140
120
100
80
60
40
20
0
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
RPM
T500

FIG.5

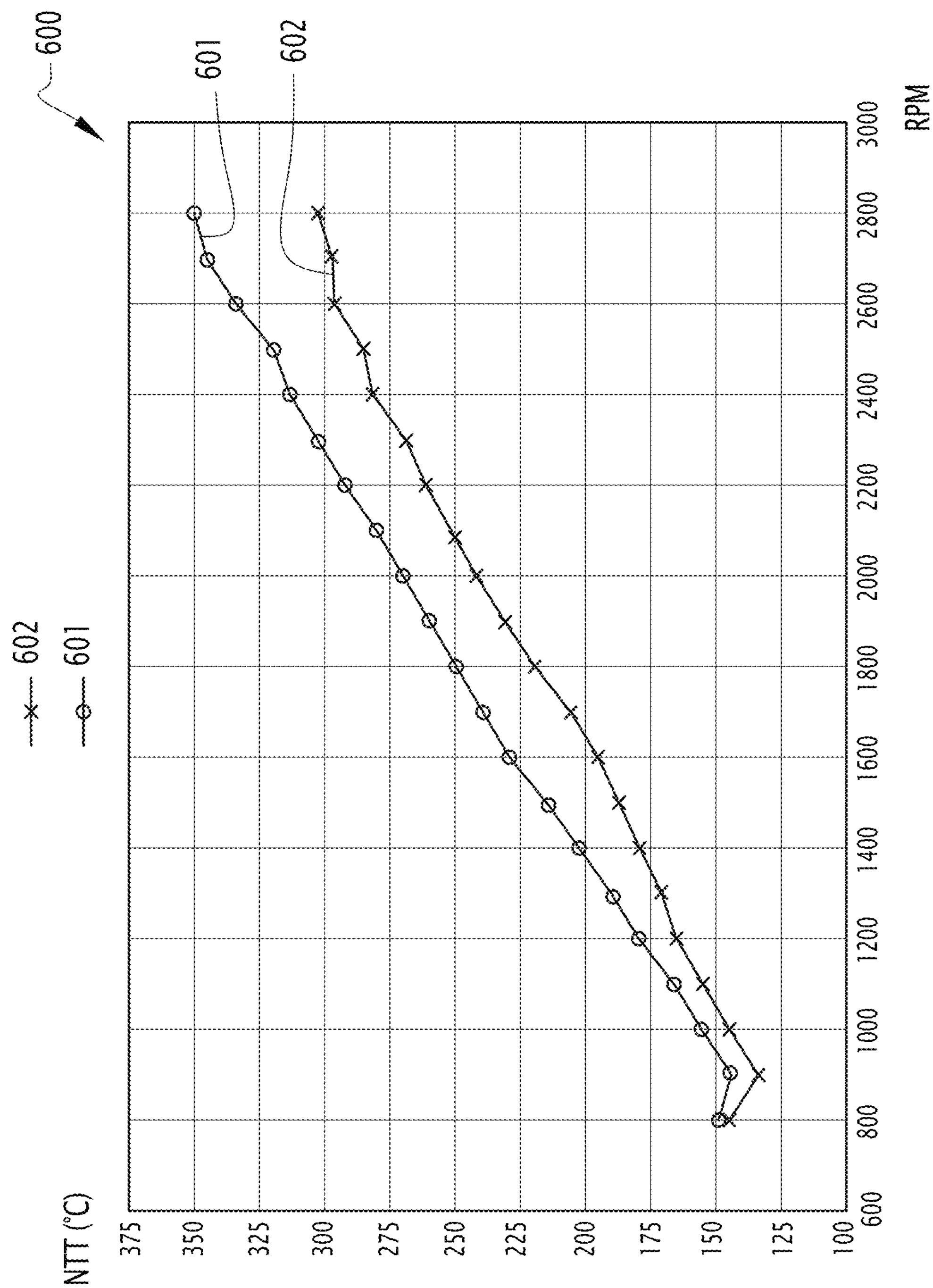

600
601
602
NTT (°C)
RPM
375 350 325 300 275 250 225 200 175 150 125 100
600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000

FIG.6

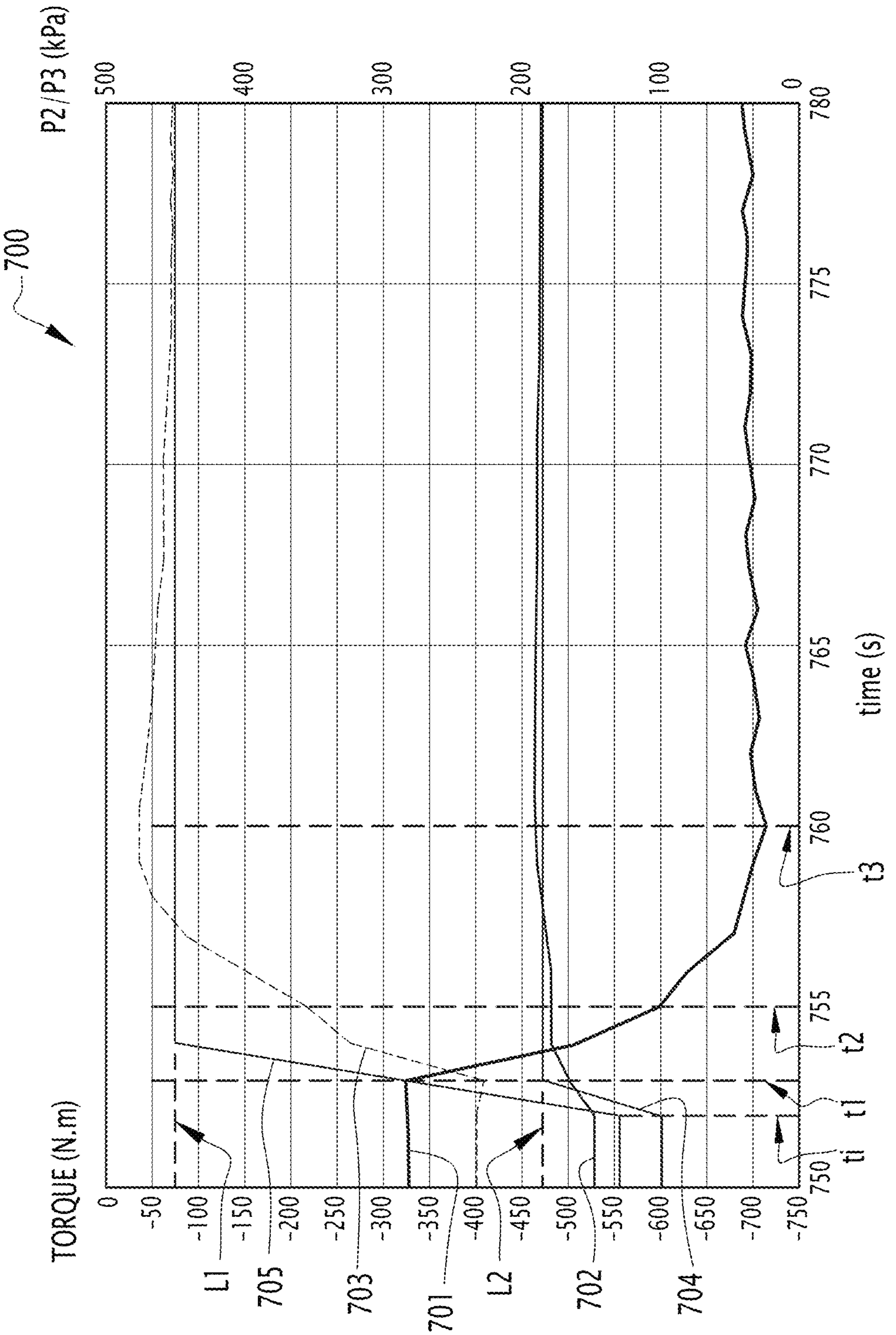

700
TORQUE (N.m)
P2/P3 (kPa)
time (s)
L1
705
703
701
L2
702
704
ti
t1
t2
t3
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600
-650
-700
-750
500
400
300
200
100
0
750
755
760
765
770
775
780

FIG.7

ENGINE BRAKE METHOD FOR OPERATING A VEHICLE WITH A TURBOCHARGED INTERNAL COMBUSTION ENGINE AND ASSOCIATED VEHICLE

CROSS REFERENCE TO RELATED APPLICATION

This application claims foreign priority to European Application No. 23191108.2 filed on Aug. 11, 2023, the disclosure and content of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The disclosure relates generally to engine brake for turbocharged engine vehicles.

BACKGROUND

Engine brake is a critical feature for commercial vehicles as it makes it possible to maintain a constant speed downhill for long periods without using the foundation brakes, which is favorable to both safety and drivability. Engine brake is typically achieved by using both a compression release system, for example a so-called Jacobs bleeder brake, and an exhaust gas restriction device, for example a proportional flap, which is installed after the turbocharger's turbine and which controls a target air pressure in the exhaust manifold. Unfortunately, this control strategy achieves limited results in terms of braking power, since closing the flap also results in decreasing the airflow going through the engine. This has several secondary negative effects, such as overheating nozzle tips of the fuel injectors—by lack of air to cool them down—, increasing oil rejection at the outlet of the turbocharger's compressor—by lack of air pressure in the compressor housing to keep its seal tight—, etc.

Alternative approaches have tried to solve these issues. For example, on engines comprising a turbocharger with moveable elements to adjust an output of the turbocharger—also called VGT—, an alternative to using the exhaust flap is to control the exhaust back-pressure with the VGT instead: this is known as "VGT braking". Increasing the exhaust back-pressure with the VGT also increases the air flow at the same time, which benefits the efficiency of the compression release system. However, since it also results in a reduced difference between intake pressure and exhaust pressure, braking power is actually not much improved with VGT braking. Another drawback of this strategy lies in its slow and sluggish response, up to several seconds, caused by the time it takes to pressurize the whole intake system.

SUMMARY

According to a first aspect of the disclosure, the invention concerns an engine brake method for operating a vehicle with a turbocharged internal combustion engine. The engine comprises:

- several cylinders, which are connected to an intake manifold, collecting fresh air, and to an exhaust manifold, collecting exhaust air from the cylinders,
- a turbocharger; with a compressor driven by a turbine, the compressor being configured to increase a boost pressure of the fresh air in the intake manifold, while the turbine is configured to be driven by the exhaust air flowing from the exhaust manifold;

- a boost pressure regulation device, which is configured to adjust the boost pressure in the intake manifold, and
- an exhaust gas restriction device, which is located downstream from the turbine and which is configured to adjust an exhaust air pressure in the exhaust manifold.

The engine brake method comprises a dual phase during which, simultaneously:

- the boost pressure regulation device regulates the air exhaust pressure in the exhaust manifold in closed loop, in order to regulate the exhaust pressure to a pre-determined first threshold, and
- the exhaust gas restriction device controls the boost pressure in closed loop, in order to regulate the boost pressure to a pre-determined second threshold.

A technical benefit may include increasing both boost pressure and air exhaust pressure, thus resulting in a higher engine brake effect. Simultaneously, the air flow through the cylinders remains at a higher level, contributing to the cooling of the injector tips. Additionally, the pressure differential between boost pressure and air exhaust pressure remains positive, preventing oil leaks through the compressor seal. On steep downhill roads, it is therefore possible to increase the load of the vehicle, and/or to drive the vehicle on steeper roads, while regulating the speed of the vehicle solely based on engine brake, i.e. without using the foundation brake. The overall safety of the vehicle is therefore improved.

Optionally in some examples, including in at least one preferred example, the engine comprises an intake throttle valve, which is arranged between the turbocharger and the intake manifold and which is configured to control the boost pressure, whereas during the dual phase, the intake throttle valve forms the boost pressure regulation device and regulates the air exhaust pressure in the exhaust manifold in closed loop. A technical benefit may include implementing the dual phase by using commonly used equipment.

Optionally in some examples, including in at least one preferred example, the turbocharger is a variable geometry turbocharger, which comprises moveable elements to adjust an output of the turbocharger, whereas during the dual phase, the variable geometry turbocharger forms the boost pressure regulation device and regulates the air exhaust pressure in the exhaust manifold in closed loop. A technical benefit may include implementing the dual phase by using commonly used equipment.

Optionally in some examples, including in at least one preferred example, the engine brake method further comprising an initial phase, prior to the dual phase. The initial phase comprises a first phase, during which the exhaust air pressure is controlled by the restriction device while the turbocharger is in open loop, so as to let exhaust air pressure to increase up to the first threshold, and a second phase, which follows the first phase and during which, once the exhaust air pressure reaches the first threshold, the restriction device is locked in position, while the turbocharger controls the air exhaust pressure in the exhaust manifold in closed loop, so as to let boost pressure increase up to the second threshold. If, during the second phase, the boost-pressure reaches the second threshold before a pre-determined time period, then the initial phase ends and the dual phase starts. A technical benefit may include ensuring a smooth, stable and rapid transition from the motoring mode of the engine to the engine brake mode.

Optionally in some examples, including in at least one preferred example, the engine further comprises bleeder valves, each bleeder valve being associated with a respective cylinder and being configured to, when activated, let compressed air to leak from the cylinders through an opening of the bleeder valve, whereas the engine brake method comprises adjusting an opening of the bleeder valve, in order to maximize a braking effect of the engine during the dual phase. A technical benefit may include improving further the engine brake performance of the vehicle.

Optionally in some examples, including in at least one preferred example, the dual phase is engaged when the engine has a speed, given in revolutions per minute, above a pre-determined third threshold. A technical benefit may include ensuring a higher engine brake effect compared to prior art methods.

According to a second aspect of the disclosure, the invention concerns a vehicle, comprising a turbocharged internal combustion engine. The vehicle is configured to implement the engine brake method according to any one of preceding claims. The engine comprises:

- several cylinders, which are connected to an intake manifold, which is configured to collect fresh air, and to an exhaust manifold, which is configured to collect exhaust air from the cylinders,
- a turbocharger; with a compressor driven by a turbine, the compressor being configured to increase a boost pressure in the intake manifold, while the turbine is configured to be driven by the exhaust air flowing from the exhaust manifold;
- a boost pressure regulation device, which is configured to adjust the boost pressure in the intake manifold, and
- an exhaust gas restriction device, which is located downstream from the turbine and which is configured to increase an exhaust air pressure in the exhaust manifold.

The second aspect of the disclosure may seek to provide a vehicle, for example a truck, with an improved engine brake capacity. A technical benefit may include allowing a higher load on downhill roads and/or allowing speed regulation on steeper downhill roads.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** represents, on two inserts a) and b); an exemplary vehicle according to the invention and an engine of this vehicle.

FIG. **2** is an exemplary synoptic diagram representing an engine brake method implemented with the vehicle of FIG. **1**.

FIGS. **3** to **6** are exemplary graphs comparing results obtained with the engine brake method according to the invention and according to prior art methods.

FIG. **7** is an exemplary graph illustrating an initial phase of the engine brake method according to the invention.

DETAILED DESCRIPTION

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

Embodiments of the present disclosure are directed to solving the problems mentioned above, by providing an engine brake method achieving a high braking power output while keeping operating parameters-such as injector cooling-within their specified ranges. In particular aspects of the disclosure relates to an engine brake method for operating a vehicle with a turbocharged internal combustion engine and to a vehicle configured to implement such an engine brake method. The disclosure can be applied to heavy-duty vehicles, such as trucks, buses, and construction equipment, among other vehicle types. Although the disclosure may be described with respect to a particular vehicle, the disclosure is not restricted to any particular vehicle.

A vehicle **10** is represented on FIG. **1***a*). The vehicle **10** is a road vehicle, in particular a truck, which comprises wheels **11**. The vehicle **10** comprises an engine **12**, which is schematically shown on FIG. **1***b*). The engine **12** is an internal combustion engine, which is configured to use fuel in order to drive the wheels **11** in rotation, in order to move the vehicle **10**. When the engine **12** uses fuel to rotate the wheel **10**, the engine **12** is in a motoring mode. On the contrary, when the engine **12** is used to waste energy, the engine **12** is in an "engine brake" mode, that is to say the engine **12** applies a braking torque to the wheels **11**. On FIG. **1**, the vehicle **10** is represented on a downhill slope S, where the vehicle **10** tends to naturally accelerate because of gravity. The engine **12** is used in the engine brake mode in order to regulate a speed of the vehicle **10**.

The engine **12** comprises a main block **14** with several cylinders **16**. In the illustrated example, the engine **12** is a four-stroke engine with six cylinders **16**. For each cylinder **16**, the four strokes include, successively, an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke.

When the engine **12** is running, during the intake stroke or each cylinder **16**, fresh air flowing through an intake manifold **20** is admitted into each cylinder **16**, through at least one intake valve. The at least one intake valve is not represented. During the exhaust stroke, air contained in the cylinder **16** is evacuated through at least one exhaust valve and collected in an exhaust manifold **22**. The at least one exhaust valve is not represented. In other words, the cylinders **16** are connected to the intake manifold **20**, which collects fresh air, and to the exhaust manifold **22**, which collects exhaust air from the cylinders **16**. When the engine **12** is in the motoring mode, fuel is injected in the cylinders and the air+fuel mix is ignited during the compression and expansion strokes. During the following exhaust stroke, the air evacuated from the cylinders **16** is hot and contains various substances and residues resulting from fuel combustion. Air containing these combustion residues is also called exhaust gas.

When the engine **12** is in the engine brake mode, no fuel is injected into the cylinders **16** and no combustion occurs. The air evacuated from the cylinders **16** during the exhaust stroke is mostly fresh air that has been admitted during the intake stroke, then compressed and expanded inside the cylinders **16** during the compression and expansion strokes.

Air flowing from the cylinders **16** into the exhaust manifold **22** is also called "exhaust air". Fresh air flowing from the intake manifold **20** into the cylinders **16** is also called "charge air". The intake manifold **20** is located upstream from the cylinders **16** relative to the normal flow of air in the engine **12**, while the exhaust manifold **22** is located downstream from the cylinders **16** relative to the normal flow of air in the engine **12**. In the following description, the notions of "upstream" and "downstream" are considered relatively to the flow of air during normal use of the engine **12**.

"Normal use" means that the engine **12** is either in the motoring mode, or in the engine brake mode.

The engine **12** also comprises a turbocharger **30**. The turbocharger **30** comprises a compressor **32** and a turbine **34**, the compressor **32** being linked to the turbine **34** by an axle **36**. The turbine **34** is configured to be driven in rotation by the exhaust air flowing from the exhaust manifold **22**, while the compressor **32** is configured to increase a pressure of the charge air flowing in the intake manifold **20** then into the cylinders **16**.

When the engine **12** is in the engine brake mode, during the compression/expansion strokes in each cylinder **16**, air pressure reaches a peak, called "peak cylinder pressure" PCP. In the schematic example of FIG. **1***b*), one of the cylinder **16** comprises a first pressure sensor, here represented figuratively by a manometer, the first pressure sensor being configured to measure air pressure within the cylinder **16**. In particular, the first pressure sensor, also referenced PCP, is configured to measure the peak cylinder pressure. Of course, in reality there is no manometer inside any one of the cylinders **16**.

A second pressure sensor P**2**, represented figuratively by a manometer, is arranged on the intake manifold **20**, the second pressure sensor P**2** being configured to measure a boost pressure, that is to say an air pressure inside the intake manifold **20**. By extension, boost pressure is also referenced P**2**. A third pressure sensor P**3**, represented figuratively by a manometer, is arranged on the exhaust manifold **22**, the third pressure sensor P**3** being configured to measure an exhaust pressure, that is to say an air pressure inside the exhaust manifold **22**. By extension, exhaust pressure is also referenced P**3**.

The engine also comprises an exhaust gas restriction device **40**, which is located downstream from the turbine **34** and which is configured to regulate the exhaust pressure P**3** in the exhaust manifold **22**. In the illustrated example, the exhaust gas restriction device **40** is a flap, also called "exhaust flap". The shape and type of the exhaust gas restriction device **40** are not limitative.

The engine **10** also comprises a fourth pressure sensor P**4**A, represented figuratively by a manometer, which is arranged downstream from the turbine **34** and which is configured to measure a turbine outlet pressure, that is to say a pressure of exhaust air at an outlet of the turbine **34**, between the turbine **34** and the exhaust gas restriction device **40**. By extension, the turbine outlet pressure is also referenced P**4**A.

The engine **10** also comprises a boost pressure regulation device **42**, which is configured to adjust the boost pressure P**2** in the intake manifold **20**. In the illustrated example, the boost pressure regulation device **42** is an intake throttle valve, which is represented by a flap and which is arranged between the turbocharger **30** and the intake manifold **20**, and which is configured to control the boost pressure P**2**. The shape and type of the boost pressure regulation device **42** are not limitative.

Schematically, braking torque from the engine **12** comes mainly from the combination of two phenomena. A first phenomenon is called pumping torque, which is caused by the exhaust pressure P**3** being higher than the boost pressure P**2**. The higher the difference between P**3** and P**2**, the higher the braking torque. A second phenomenon is called compression release torque, or compression brake. Each cylinder **16** is advantageously equipped with a bleeder valve **17**, which is configured to let the air compressed inside the cylinder **16** to leak from the cylinder **16** through an opening of the bleeder valve **17** when the engine **12** is in the engine brake mode, while each bleeder valve **17** remains closed when the engine **12** is in the motoring mode.

Without a bleeder valve, when air is compressed in the cylinders **16** during the compression stroke, the mechanical energy invested in compressing air is almost entirely recovered by the expansion within the cylinder **16** during the expansion stroke. Thanks to the bleeder valve **17**, the compressed air is released outside the cylinder **16** through the opening of the bleeder valve **17**, and the energy that went into making the compression is wasted by releasing the compressed air instead of letting it expand inside the cylinder **16**. The higher the peak cylinder pressure PCP, prior to releasing this compressed air, the higher the wasted energy, and the higher the braking torque generated by compression brake.

According to some examples, the bleeder valve **17** is a specific device, different from the intake and exhaust valves. Alternatively, the bleeder valve **17** comprises an actuator that is configured to slightly open one or more existing exhaust valve(s) when the engine **12** is in the engine brake mode. Such type of bleeder valve is also known as "Jacobs valve", and compression brake using such a Jacobs valve is also called "Jacobs brake".

In short, when the engine **12** is in the engine brake mode, maximizing braking torque involves maximizing both the peak cylinder pressure PCP and the pressure difference between exhaust pressure and intake pressure, P**3**-P**2**. To achieve this, the engine **12** is configured to implement an engine brake method, the engine brake method comprising a phase, called "dual phase" **101**, during which, simultaneously:

- the boost pressure regulation device **42** regulates the air exhaust pressure P**3** in the exhaust manifold **22** in closed loop, in order to regulate the exhaust pressure to a pre-determined first threshold, and
- the exhaust gas restriction device **40** controls the boost pressure P**2** in closed loop, in order to regulate the boost pressure P**2** to a pre-determined second threshold.

Advantageously, the engine brake method comprises adjusting the opening of the bleeder valve **17** to a specific predetermined target value, in order to maximize a braking torque of the engine **12** during the dual phase. The target value of the opening of the bleeder valve depends on the type, size, power, etc., of the engine **12**.

Using the boost pressure regulation device **42** to control the exhaust pressure P**3** in closed loop makes the turbocharger **30** draw a lot of fresh air into the engine **12**, which increases peak cylinder pressure PCP and cools down the injector tips. Using the exhaust gas restriction device **40** to control P**2** in closed loop decreases an expansion ratio of the turbine **34**, thus limiting boost pressure P**2** to values significantly lower than P**3** and contributing to a higher pumping torque. The pressure differential P**3**-P**2** remains positive, which keeps the compressor **32**'s seal tight.

Results and benefits of the dual phase are illustrated on FIGS. **3** to **6**.

A graph **300** is shown on FIG. **3**. The graph **300** shows the evolution, for an exemplary vehicle **10**, of the exhaust pressure P**3**—expressed in kilo Pascal, or kPa—vs. a speed of the engine **12**—expressed in revolutions per minute, or RPM—.

The graph **300** comprises a first curve **301**, which illustrates the exhaust pressure P**3** when the engine **12** is controlled according to a prior art method. Within the scope of the present description, engine brake according to the prior art method means that the exhaust air pressure P**3** is controlled by the restriction device **40** while the turbocharger **30** is in open loop. The graph **300** comprises a second curve **302**, which illustrated the exhaust pressure P**3** when the engine **12** is controlled with the dual phase **101** method according to the invention.

As seen on the graph **300**, the second curve **302** is significantly above the first curve **301** when the engine speed is higher than a pre-determined threshold T**300**, which is equal to 1800 RPM in the illustrated example. In other words, thanks to the invention, the exhaust pressure P**3** is higher when the engine speed is above the threshold T**300**.

A graph **400** is shown on FIG. **4**. The graph **400** shows the evolution, for an exemplary vehicle **10**, of the boost pressure P**2**—expressed in kPa—vs. the speed of the engine **12**—expressed in RPM—.

The graph **400** comprises a first curve **401**, which illustrates the boost pressure P**2** when the engine **12** is controlled according to the prior art method. The graph **400** comprises a second curve **402**, which illustrated the boost pressure P**2** when the engine **12** is controlled with the dual phase **101** method according to the invention.

As seen on the graph **400**, for all illustrated engine speed, the second curve **402** is significantly above the first curve **401**. In other words, thanks to the invention, the boost pressure P**2** is higher when the engine **12** is controlled with the method according to the invention compared to when the engine **12** is controlled with the prior art method. In particular, in the illustrated example, when the engine speed is above a threshold T**400**, which is here equal to 1400 RPM, the boost pressure P**2** when the engine **12** is controlled with the method according to the invention is at least ten times higher than the boost pressure P**2** when the engine **12** is controlled with the prior art method.

A graph **500** is shown on FIG. **5**. The graph **500** shows the evolution, for an exemplary vehicle **10**, of the engine brake power-expressed in kilo Watt, or kW-vs. the speed of the engine **12**—expressed in RPM—.

The graph **500** comprises a first curve **501**, which illustrates the engine brake power when the engine **12** is controlled according to the prior art method. The graph **500** comprises a second curve **502**, which illustrated the engine brake power when the engine **12** is controlled with the dual phase **101** method according to the invention.

As seen on the graph **500**, the second curve **502** is significantly above the first curve **501** when the engine speed is higher than a pre-determined threshold T**500**, which is equal to 1400 RPM in the illustrated example. In other words, thanks to the invention, the boost pressure P**2** is higher when the engine **12** is controlled with the method according to the invention compared to when the engine **12** is controlled with the prior art method.

In other words, in order to benefit from a higher braking power, the dual phase **101** is engaged when the engine speed is above a pre-determined threshold. In the illustrated example, this threshold is equal to 1400 RPM.

Thanks to control method according to the invention, it is possible to control simultaneously both boost pressure P**2** and exhaust pressure P**3**, which results in an engine brake power significantly higher than what was achievable with the prior art method.

A graph **600** is shown on FIG. **6**. The graph **600** shows the evolution, for an exemplary vehicle **10**, of a temperature of the tip of an injector's nozzle—nozzle tip temperature, or NTT, expressed in degrees Celsius, or ° C.—vs. the speed of the engine **12**—expressed in RPM—.

The graph **600** comprises a first curve **601**, which illustrates the nozzle tip temperature NTT when the engine **12** is controlled with the prior art method. The graph **600** comprises a second curve **602**, which illustrated the nozzle tip temperature NTT when the engine **12** is controlled with the dual phase **101** method according to the invention.

As seen on the graph **600**, for all illustrated engine speed, the second curve **602** is below the first curve **601**. In other words, thanks to the invention, the nozzle tip temperature NTT is lower when the engine **12** is controlled with the method according to the invention compared to when the engine **12** is controlled with prior art methods. This is caused by the higher air flow flowing through the cylinders **16**, since—among others—the boost pressure P**2** is higher in the dual mode compared to prior art methods, as illustrated on graph **400**.

When the vehicle **10** is running, moving between flat or uphill roads to downhill roads, the engine **12** may transition between motoring mode and engine brake mode. The dual phase **101** method correspond to an established state of the engine **12** in the engine brake method. Prior to the dual phase **101**, the engine brake method according to the invention also comprises an initial phase **100**, which is implemented to ensure the transition between the motoring mode and the dual phase **101** of the engine brake mode.

The initial phase **100** is divided in two sub-phase, which include and first phase **100**A and a second phase **100**B, which follows the first phase **100**A.

As the engine **12** is initially in the motoring mode, and the engine **12** is controlled to switch to the engine brake mode. The engine speed, which is linked to the rotation speed of the wheels **11**, is supposed to remain sensibly constant during the initial phase. During the first phase **100**A, the exhaust air pressure P**3** is controlled by the restriction device **40** while the turbocharger **30** is in open loop, so as to let exhaust air pressure P**3** to increase up to a pre-determined first threshold L**1**.

Once the exhaust air pressure P**3** reaches the first threshold L**1**, the second phase **100**B starts. During the second phase **100**B, the restriction device **40** is locked in position—in other words the restriction device **40** does not regulate exhaust air pressure P**3**—, while the turbocharger **30** controls the air exhaust pressure P**3** in the exhaust manifold **22** in closed loop, so as to let boost pressure P**2** increase up to a pre-determined second threshold L**2**.

During the second phase **100**B, if the boost-pressure P**2** reaches the second threshold before a pre-determined time period, then the initial phase ends and the dual phase **101** starts. If the boost-pressure P**2** does not reach the second threshold, then the dual phase **101** does not start, and the engine reverts to the first phase **100**A.

A graph **700** is shown on FIG. **7**. The graph **700** shows the evolution of several parameters of the engine **12** during the initial phase **100** and dual phase **101**. The horizontal axis is a time axis—expressed in seconds—. In the example of FIG. **7**, engine speed is considered constant.

The graph **700** comprises a first curve **701**, which shows the evolution of a torque—expressed in Newton×meter, or N·m—of the engine **12**. On the left hand side vertical axis, the torque is negative, since the engine **12** is in the engine brake mode.

The graph **700** comprises a second curve **702**, which shows the evolution of the exhaust pressure P**3**, expressed in kPa relative to the right hand side vertical axis. The graph **700** comprises a second curve **702**, which shows the evolution of the boost pressure P**2**, expressed in kPa relative to the right hand side vertical axis. The graph **700** comprises a third curve **703**, which shows the evolution of the exhaust pressure P**3**, expressed in kPa relative to the right hand side vertical axis. The graph **700** comprises a fourth curve **704**, which shows the evolution of a set-point of the boost pressure P**2**, expressed in kPa relative to the right hand side vertical axis. The graph **700** comprises a fifth curve **705**, which shows the evolution of a set-point of the exhaust pressure P**3**, expressed in kPa relative to the right hand side vertical axis.

In the illustrated example, at an initial instant ti, the set-point of the exhaust pressure P**3** is gradually set to the first threshold L**1**. The initial instant ti marks the beginning of the first phase **100**A. In the illustrated example, starting at the initial instant ti, the set-point of the boost pressure P**2** is also gradually set to the second threshold L**2**. The torque **701** shows an initial plateau, around −330 N·m, prior to the initial instant t_i. The exhaust pressure P**3** is controlled by the restriction device **40**.

At a first instant t_1, which is posterior to the initial instant t_i, the exhaust pressure P**3** starts to rise, in order to narrow the gap with the first threshold L**1**. Consequently, the torque **701** sharply decreases. In other words, the effect of the engine brake increase. In the illustrated example, the difference between the first instant t_1 and initial instant ti is about 0.1 s.

From the first instant t_1, the boost pressure P**2** also starts to rise, narrowing the gap with the second threshold L**2**. At a second instant t_2, which is posterior to the first instant t_1, the boost pressure P**2** is sensibly equal to the second threshold L**2**, while the exhaust pressure P**3** continues to rise, and the torque **701** continues to decrease.

At a third instant t_3, which is posterior to the second instant t_2, the exhaust pressure P**3** reaches a maximal value, which is sensibly equal to the first threshold L**1**. Between the second instant t_2 and third instant t_3, the torque **701** continues to decrease.

The third instant t_3 marks the end of the first phase **100**A and the beginning of the second phase **100**B. In the illustrated example, the boost pressure P**2** is already sensibly equal to the second threshold L**2**, so the second phase **100**B ends immediately and the dual phase **101** starts from the third instant t_3 on. In the illustrated example, a duration of the initial phase **100** is sensibly equal to the difference between the third instant t_3 and the first instant t_1, which is here around 0.7 s.

More generally, if, during the second phase **100**B, the boost-pressure P**2** does not reach the second threshold L**2** before a pre-determined time period, then the initial phase restarts, back to the first phase **100**A. This situation might appear in abnormal situation, for example if one of the components of the engine **12** is dysfunctioning. In a normal situation, if during the second phase **100**B, the boost-pressure P**2** reaches the second threshold L**2** before the pre-determined time period, then the initial phase **100** ends and the dual phase **101** starts.

During the dual phase **101**, the boost pressure regulation device **42** regulates the air exhaust pressure P**3** in the exhaust manifold **22** in closed loop, in order to regulate the exhaust pressure P**3** to the pre-determined first threshold L**1**, while the exhaust gas restriction device **40** controls the boost pressure P**2** in closed loop, in order to regulate the boost pressure P**2** to the pre-determined second threshold L**2**. As shown on FIG. **7**, during the dual phase **101**, the exhaust pressure P**3**, the boost pressure P**2** and the torque **701** are relatively stable.

In the illustrated example, the boost pressure regulation device **42** is the intake throttle valve. During the dual phase **101**, the intake throttle valve forms the boost pressure regulation device **42** and regulates the air exhaust pressure in the exhaust manifold **22** in closed loop.

In a non-illustrated alternative embodiment, the turbocharger **30** is a variable geometry turbocharger VGT, which comprises moveable elements to adjust an output of the turbocharger **30**, thus forming the boost pressure regulation device **42** when the engine **12** is in the motoring mode. During the dual phase **101** of the engine brake method, the variable geometry turbocharger VGT forms the boost pressure regulation device **42** and regulates the air exhaust pressure P**3** in the exhaust manifold **22** in closed loop.

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

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

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

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

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

What is claimed is:

1. An engine brake method for operating a vehicle with a turbocharged internal combustion engine, wherein:

the engine comprises:

several cylinders, which are connected to an intake manifold, collecting fresh air, and to an exhaust manifold, collecting exhaust air from the cylinders;

a turbocharger, with a compressor driven by a turbine, the compressor being configured to increase a boost pressure of the fresh air in the intake manifold, while the turbine is configured to be driven by the exhaust air flowing from the exhaust manifold;

a boost pressure regulation device, which is configured to adjust the boost pressure in the intake manifold; and

an exhaust gas restriction device, which is located downstream from the turbine and which is configured to regulate an air exhaust pressure in the exhaust manifold,

the engine brake method comprises a dual phase during which, simultaneously:

the boost pressure regulation device regulates the air exhaust pressure in the exhaust manifold in closed loop, in order to regulate the exhaust pressure to a pre-determined first threshold, and

the exhaust gas restriction device controls the boost pressure in closed loop, in order to regulate the boost pressure to a pre-determined second threshold.

2. The engine brake method according to claim **1**, wherein:

the engine comprises an intake throttle valve, which is arranged between the turbocharger and the intake manifold and which is configured to control the boost pressure, and

during the dual phase, the intake throttle valve forms the boost pressure regulation device and regulates the air exhaust pressure in the exhaust manifold in closed loop.

3. The engine brake method according to claim **1**, wherein:

the turbocharger is a variable geometry turbocharger, which comprises moveable elements to adjust an output of the turbocharger, and

during the dual phase, the variable geometry turbocharger forms the boost pressure regulation device and regulates the air exhaust pressure in the exhaust manifold in closed loop.

4. The engine brake method according to claim **1**, further comprising an initial phase, prior to the dual phase, wherein:

the initial phase comprises:

a first phase, during which the air exhaust pressure is controlled by the restriction device while the turbocharger is in open loop, so as to let exhaust air pressure to increase up to the first threshold, and

a second phase, which follows the first phase and during which, once the exhaust air pressure reaches the first threshold, the restriction device is locked in position, while the turbocharger controls the air exhaust pressure in the exhaust manifold in closed loop, so as to let boost pressure increase up to the second threshold, and

if, during the second phase, the boost-pressure reaches the second threshold before a pre-determined time period, then the initial phase ends and the dual phase starts.

5. The engine brake method according to claim **1**, wherein:

the engine further comprises bleeder valves, each bleeder valve being associated with a respective cylinder and being configured to, when activated, let compressed air to leak from the cylinders through an opening of the bleeder valve, and

the engine brake method comprises adjusting an opening of the bleeder valve, in order to maximize a braking effect of the engine during the dual phase.

6. The engine brake method according to claim **1**, wherein:

the dual phase is engaged when the engine has a speed, given in revolutions per minute, above a pre-determined third threshold.

7. A vehicle, comprising a turbocharged internal combustion engine, wherein:

the vehicle is configured to implement the engine brake method according to claim **1**,

the engine comprises:

several cylinders, which are connected to an intake manifold, which is configured to collect fresh air, and to an exhaust manifold, which is configured to collect exhaust air from the cylinders,

a turbocharger, with a compressor driven by a turbine, the compressor being configured to increase a boost pressure in the intake manifold, while the turbine is configured to be driven by the exhaust air flowing from the exhaust manifold;

a boost pressure regulation device, which is configured to adjust the boost pressure in the intake manifold,

an exhaust gas restriction device, which is located downstream from the turbine and which is configured to adjust an exhaust air pressure in the exhaust manifold.

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