

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

pressure value. The method further comprises the steps of: storing the thus created transfer functions for the engine cylinders (C1, C2, C3, C4, C5, C6); and, during vehicle operation, determining the manifold pressure in connection to the individual cylinders (C1, C2, C3, C4, C5, C6) based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values. The present invention also relates to a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The present invention also relates to a vehicle. The present invention also relates to a computer program and a computer readable medium.

METHOD AND CONTROL DEVICE FOR DETERMINING MANIFOLD
PRESSURE IN A MANIFOLD CONFIGURATION IN CONNECTION TO
INDIVIDUAL CYLINDERS OF AN INTERNAL COMBUSTION ENGINE

5 TECHNICAL FIELD

The invention relates to a method performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The invention also relates to a control device for determining manifold pressure in a manifold
10 configuration in connection to individual cylinders of an internal combustion engine. The invention further relates to a vehicle. The invention in addition relates to a computer program and a computer readable medium.

BACKGROUND ART

15 Increasing demands for more efficient internal combustion engines and stricter legislations on exhaust emissions require more accurate control of the engine operating parameters.

Internal combustion engines comprise a manifold configuration. The manifold configuration comprises an intake manifold arrangement for providing
20 pressurized air to the cylinders of the engine during engine operation and an exhaust manifold arrangement for exhausting combusted fuel from the cylinder of the engine.

The intake air manifold arrangement is part of the air intake system of the engine. One of the most important parameters of the air intake system is the
25 intake manifold pressure of the intake manifold arrangement of the manifold configuration. It is directly related to the total charge flowing from the intake manifold arrangement to the cylinders of the engine and is directly influencing

the combustion event and consequently, the emissions control. The intake manifold pressure may be detected by means of a pressure sensor arranged in the intake manifold arrangement. However, due to increasing demands for more efficient internal combustion engines and stricter legislations on exhaust emissions a more accurate control of the intake manifold pressure is required. One way of obtaining more accurate control of the intake manifold pressure is to arrange pressure sensors in the intake manifold arrangement in connection to each cylinder. This is however costly.

Another important parameter to be monitored is the exhaust manifold pressure of the exhaust manifold arrangement of the manifold configuration. The exhaust manifold pressure is a parameter that is used for the estimation of the engine's volumetric efficiency. Moreover, it is considered critical in engines with Exhaust Gas Regulation (EGR) systems as the emissions are directly affected by the variation of EGR mass flow. One way of obtaining more accurate determination of the exhaust manifold pressure is to arrange pressure sensors in the exhaust manifold arrangement in connection to each cylinder. This is however costly.

Utilizing so called virtual sensors, i.e. using inputs from physical sensors to estimate the values of the intake manifold pressure and exhaust manifold pressure, may be a way to provide more accurate control of the engine parameters. Virtual sensors may require a lot of computational time and computational space.

OBJECTS OF THE INVENTION

An object of the present invention is to provide a method performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine which is accurate and efficient both with regard to costs and required computational time and space.

Another object of the present invention is to provide a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine which is accurate and efficient both with regard to costs and required computational time and space.

- 5 Another object of the present invention is to provide a vehicle comprising such a control device.

SUMMARY OF THE INVENTION

10 These and other objects, apparent from the following description, are achieved by a method, a control device, a vehicle, a computer program and a computer readable medium, as set out in the appended independent claims. Preferred embodiments of the method and the control device are defined in appended dependent claims.

15 Specifically an object of the invention is achieved by a method performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The manifold configuration comprises an intake manifold arrangement and an exhaust manifold arrangement. The manifold pressures are determined in the intake manifold arrangement in connection to individual cylinders and/or the
20 exhaust manifold arrangement in connection to individual cylinders. The method comprises the step of, for calibration, creating a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in
25 connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value. The

method further comprises the steps of: storing the thus created transfer functions for the engine cylinders; and, during vehicle operation, determining the manifold pressure in connection to the individual cylinders based upon pressure coefficient values of the thus stored transfer functions and
5 corresponding detected manifold reference pressure values.

Hereby the local manifold pressure in connection to the individual cylinders may be accurately determined during vehicle operation by using only a reference pressure sensor arrangement, i.e. without the need of pressure sensors arranged in connection to each individual cylinder. This is valid for
10 both the intake manifold arrangement and the exhaust manifold arrangement of the manifold configuration of the internal combustion engine. Thus, for the intake manifold arrangement, during vehicle operation, the pressure in connection to the individual cylinders of the intake manifold arrangement, may with this method be accurately determined without the need of physical
15 pressure sensors arranged in the intake manifold arrangement in connection to the individual cylinders, only reference pressure sensor arrangement arranged in the intake manifold arrangement being needed. Thus, for the exhaust manifold arrangement, during vehicle operation, the pressure in connection to the individual cylinders of the exhaust manifold arrangement,
20 may with this method be accurately determined without the need of physical pressure sensors arranged in the exhaust manifold arrangement in connection to the individual cylinders, only reference pressure sensor arrangement arranged in the exhaust manifold arrangement being needed. By thus basing each pressure coefficient value upon a ratio between a local manifold pressure
25 value and a corresponding manifold reference pressure value a load independence is obtained, thus saving computational time and computational space. Further, calibration time hereby also be saved.

According to an embodiment of the method each pressure coefficient value being based upon a ratio between a local manifold pressure value and a

corresponding manifold reference pressure value and further being based upon a determined heat capacity ratio and a determined Mach number.

According to an embodiment of the method the pressure coefficient values are determined based upon a linearized pressure coefficient model. By thus using
5 a linearized pressure coefficient model accurate determination of manifold pressures may be obtained in an easy and efficient way.

According to an embodiment of the method, for calibration, for the intake manifold arrangement, the local manifold pressure values in connection to each individual cylinder are detected by means of local pressure sensors
10 arranged in the intake manifold arrangement in connection to the respective cylinder, and the manifold reference pressure values are detected by means of a reference pressure sensor arrangement arranged in the intake manifold arrangement.

According to an embodiment of the method, for calibration, for the exhaust manifold arrangement, the local manifold pressure values in connection to each individual cylinder are detected by means of local pressure sensors
15 arranged in the exhaust manifold arrangement in connection to the respective cylinder, and the manifold reference pressure values are detected by means of a reference pressure sensor arrangement arranged in the exhaust manifold
20 arrangement.

According to an embodiment of the method, during vehicle operation, for the intake manifold arrangement, the detected manifold reference pressure values are detected by means of a reference pressure sensor arrangement arranged in the intake manifold arrangement.

25 According to an embodiment of the method, during vehicle operation, for the exhaust manifold arrangement, the detected manifold reference pressure values are detected by means of a reference pressure sensor arrangement arranged in the exhaust manifold arrangement.

Specifically an object of the invention is achieved by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The manifold configuration comprises an intake manifold arrangement and an exhaust manifold arrangement. The manifold pressures are determined in the intake manifold arrangement in connection to individual cylinders and/or the exhaust manifold arrangement in connection to individual cylinders. The control device is configured to, for calibration, create a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value. The control device is further configured to store the thus created transfer functions for the engine cylinders; and, during vehicle operation, determine the manifold pressure in connection to the individual cylinders based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

According to an embodiment of the control device each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based upon a determined heat capacity ratio and a determined Mach number.

According to an embodiment of the control device the control device is configured to determine the pressure coefficient values based upon a linearized pressure coefficient model.

According to an embodiment of the control device, for calibration, for the intake manifold arrangement, the control device is configured to detect the local

manifold pressure values in connection to each individual cylinder by means of local pressure sensors arranged in the intake manifold arrangement in connection to the respective cylinder, and wherein the control device is configured to detect the manifold reference pressure values by means of a
5 reference pressure sensor arrangement arranged in the intake manifold arrangement.

According to an embodiment of the control device, for calibration, for the exhaust manifold arrangement, the control device is configured to detect the local manifold pressure values in connection to each individual cylinder by
10 means of local pressure sensors arranged in the exhaust manifold arrangement in connection to the respective cylinder, and wherein the control device is configured to detect the manifold reference pressure values by means of a reference pressure sensor arrangement arranged in the exhaust manifold arrangement.

15 According to an embodiment of the control device, during vehicle operation, for the intake manifold arrangement, the control device is configured to detect manifold reference pressure values by means of a reference pressure sensor arrangement arranged in the intake manifold arrangement.

According to an embodiment of the control device, wherein, during vehicle
20 operation, for the exhaust manifold arrangement, the control device is configured to detect manifold reference pressure values by means of a reference pressure sensor arrangement arranged in the exhaust manifold arrangement.

Specifically an object of the invention is achieved by a vehicle comprising a
25 control device as set out herein

Specifically an object of the invention is achieved by a computer program for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine, said computer program comprising program code which, when run on an control device or another

computer connected to the control device, causes the control device to perform the method as set out herein.

Specifically an object of the invention is achieved by a computer readable medium comprising instructions which, when executed by a computer, cause
5 the computer to carry out the method as set out herein.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention reference is made to the following detailed description when read in conjunction with the accompanying
10 drawings, wherein like reference characters refer to like parts throughout the several views, and in which:

Fig. 1 schematically illustrates a side view of a vehicle according to an embodiment of the present invention;

Fig. 2 schematically illustrates an internal combustion engine according to an
15 embodiment of the present disclosure;

Fig. 3 schematically illustrates the internal combustion engine in fig. 2 according to an embodiment of the present disclosure;

Fig. 4 schematically illustrates a block diagram of a control device for determining manifold pressure in a manifold configuration in connection to
20 individual cylinders of an internal combustion engine according to an embodiment of the present disclosure;

Fig. 5a schematically illustrates a manifold configuration of the engine in fig. 3 during calibration according to an embodiment of the present disclosure;

Fig. 5b schematically illustrates the manifold configuration in fig. 5a during
25 vehicle operation according to an embodiment of the present disclosure;

Fig. 6 schematically illustrates a flowchart of a method performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine according to an embodiment of the present disclosure;

- 5 Fig. 7 schematically illustrates pressure coefficients for an engine cycle for a certain engine speed and various loads;

Fig. 8 schematically illustrates a transfer function for a cylinder comprising linearized pressure coefficient values for range of crank angle values and a range of engine speed values;

- 10 Fig. 9 schematically illustrates a computer according to an embodiment of the present invention.

DETAILED DESCRIPTION

- Hereinafter the term “link” refers to a communication link which may be a
15 physical connector, such as an optoelectronic communication wire, or a non-physical connector such as a wireless connection, for example a radio or microwave link.

Fig. 1 schematically illustrates a side view of a vehicle V according to an embodiment of the present invention.

- 20 The exemplified vehicle V is a heavy vehicle in the shape of a truck. The vehicle V is travelling on a road R. The exemplified vehicle is operated by means of an internal combustion engine. The exemplified vehicle may be a hybrid vehicle. The exemplified vehicle may be an autonomous vehicle.

- The vehicle V may comprise a control device for determining manifold
25 pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The vehicle V comprises, according to an

embodiment, a control device 100 for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine according to fig. 4.

- 5 The vehicle V is, according to an embodiment, arranged to be operated in accordance with a method M1 for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine according to fig. 6.

Fig. 2 schematically illustrates an internal combustion engine E according to an embodiment of the present disclosure.

- 10 The engine E comprises a crankshaft CS connected to a flywheel FW, and a set of cylinders of which one cylinder C1 is shown, distributed along said crankshaft CS for rotating said crankshaft CS during operation of the engine.

- The cylinder C1 is connected to the crankshaft via a connecting rod R connected to a piston P1 of the cylinder C1. Each cylinder of the set of
15 cylinders is arranged to house a piston of which the piston P1 for the cylinder C1 is shown. The piston P1 is movably arranged within the cylinder C1 for performing strokes as explained below.

The engine E comprises fuel injectors F for injecting fuel into the cylinder C for combustion.

- 20 The engine E is arranged to provide a four stroke cycle. The engine according to the present disclosure may be an engine arranged to provide any suitable stroke cycle, e.g. a two stroke cycle or a six stroke cycle. The complete four stroke cycle forms a single thermodynamic cycle from which mechanical work will be extracted for operating a vehicle. For a complete four stroke cycle the
25 crankshaft will turn two revolutions, this being the engine cycle.

When the piston P is farthest from the crankshaft CS is known as the top dead centre TDC and when the piston P is closest to the crankshaft CS is known as

the bottom dead centre BDC. A dead centre is when the connecting rod R and the crankshaft CS align.

The strokes comprise an intake stroke (TDC to BDC) filling the cylinder C with air, a compression stroke (BDC to TDC) where the air is compressed and at
5 the end of which fuel is injected for combustion, an expansion stroke (TDC to BDC) where the combustion is completed and an exhaust stroke (BDC to TDC).

The crankshaft angle α may according to a variant determined by means of a sensor unit arranged in connection to the flywheel FW.

10 Fig. 3 schematically illustrates the internal combustions engine E in fig. 2 according to an embodiment of the present disclosure.

The engine E in fig. 3 is shown during engine operation illustrating the gas flow during engine operation.

The engine E according to schematically illustrated in fig. 3 is a turbocharged
15 diesel engine. In this example an engine E with six cylinders C1, C2, C3, C4, C5, C6 is shown. The engine E comprises an engine block 10 for housing the cylinders and other engine operation components.

The engine E is arranged to provide a four stroke cycle. The complete four stroke cycle forms a single thermodynamic cycle from which mechanical work
20 will be extracted for operating a vehicle.

The strokes comprise an intake stroke filling the respective cylinder C1-C6 with air, a compression stroke where the air is compressed and at the end of which fuel is injected for combustion, here illustrated with injection of fuel F into cylinder C6, an expansion stroke where the combustion is completed and an
25 exhaust stroke.

The engine E further comprises an air filter 20 through which ambient air A1 is arranged to pass so that filtered air A2 is obtained.

The engine E comprises a turbocharger 30 having a compressor 32, a turbine 34 and a shaft 36 operably connecting the compressor 32 and turbine 36. The compressor 32 is arranged to compress the filtered air A2 so that compressed air A3 is obtained.

- 5 The engine E comprises an intercooler 40 for cooling the compressed air A3 such that cooled compressed air A4 is obtained.

The engine E comprises an intake manifold arrangement 50 for distributing the air, i.e. the compressed air A4 to the cylinders C1-C6.

- 10 The engine E may comprise a throttle valve V1 arranged to control the distribution of air A4 to the cylinders C1-C6.

The engine E comprises an exhaust manifold arrangement 60 for distributing exhaust gas G1 from the cylinders C1-C6 to the turbine 34, the exhaust gas being arranged to pass the turbine 34 for operating the turbocharger 30 such that the compressor 32 compresses the filtered air A2.

- 15 The intake manifold arrangement 50 and exhaust manifold arrangement 60 are comprised in a manifold configuration M of the engine E. Thus, the engine E comprises a manifold configuration M. The manifold configuration M comprises the intake manifold arrangement 50 and exhaust manifold arrangement 60.

- 20 The exhaust manifold 60 may comprise a waste gate 62 for allowing exhaust gas to bypass the turbine 34 and further to the exhaust pipe 64. The engine E, when having a waste gate 62, comprises a valve V2 arranged to control the distribution of exhaust gas through the waste gate 62.

- 25 The engine E may comprise an exhaust gas brake V3 arranged downstream of the turbine 34 and downstream of the waste gate 62. When activated, the exhaust gas brake V3 is configured to provide an exhaust back pressure by rendering exhaust gas flow through the exhaust pipe 64 more difficult. The exhaust back pressure is used for braking the engine speed. The exhaust back

pressure thus created increases engine temperature due to the thus increased load. The exhaust back pressure may be used for increasing engine temperature and exhaust gas temperature, this being used at low engine speeds as the exhaust gases at low engine speeds do not reach high enough
5 temperatures in order for the exhaust treatment to function efficiently. The exhaust gas brake V3 comprises a valve configuration for controlling the exhaust gas flow through the exhaust pipe 64.

The engine E comprises an exhaust treatment system 70 arranged to treat the exhaust gas in order to reduce emissions so that treated exhaust gases G2
10 exits the exhaust gas pipe 64.

Fig. 3 thus illustrates the gas flow through the engine E. Ambient air A1 enters through the air filter 20, is compressed in the compressor 32 and led through the intercooler 40 to the intake manifold arrangement 50 before entering the cylinders 1-6. Fuel F is added by injection into the cylinders and after
15 combustion, the exhaust gas G1 pass through the turbine 34 to the exhaust treatment system 70.

The present invention relates to determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine, as described with reference to fig. 4, 5a-b and fig. 8. For the intake
20 manifold arrangement the intake manifold pressures are determined in the intake manifold arrangement in connection to individual cylinders. For the exhaust manifold arrangement the exhaust manifold pressures are determined in the exhaust manifold arrangement in connection to individual cylinders.

The intake manifold arrangement 50 schematically illustrated in fig. 3 has one
25 bank for all six branches connected to the respective cylinder C1, C2, C3, C4, C5, C6. The intake manifold arrangement according to the present disclosure may have any configuration. For a six cylinder engine the intake manifold arrangement according to the present disclosure may have two banks, each

bank having three branches connected to three of the cylinders of the six cylinder engine.

The exhaust manifold arrangement 60 schematically illustrated in fig. 3 has one bank for all six branches connected to the respective cylinder C1, C2, C3, C4, C5, C6. The exhaust manifold arrangement according to the present disclosure may have any configuration. For a six cylinder engine the exhaust manifold arrangement according to the present disclosure may have two banks, each bank having three branches connected to three of the cylinders of the six cylinder engine.

10 According to an embodiment, when detecting the pressure in the exhaust manifold arrangement according to the present disclosure, at least one pressure sensor for each bank of the exhaust manifold arrangement is used.

In fig. 3 the gas flow through a turbocharged diesel engine E is shown. The invention is equally applicable to any internal combustion engine.

15 The engine according to the present disclosure could be any suitable internal combustion engine with any suitable number of cylinders. The internal combustion engine according to the present invention could for example be a 5-cylinder engine, a 6-cylinder engine or an 8-cylinder engine. The cylinders could be in any suitable alignment, for example inline engine or a V-engine.

20 Fig. 4 schematically illustrates a block diagram of a control device 100 for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine according to an embodiment of the present disclosure.

The control device 100 for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine may be comprised in a system I for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine.

The control device may be implemented as a separate entity or distributed in two or more physical entities. The control device may comprise one or more computers. The control device may thus be implemented or realised by the control device comprising a processor and a memory, the memory comprising
5 instructions, which when executed by the processor causes the control device to perform the herein disclosed method.

The control device 100 may comprise one or more electronic control units, processing units, computers, server units or the like for determining vehicle operation of at least one vehicle. The control device 100 may comprise control
10 device such as one or more electronic control units arranged on board a vehicle. The control device 100 may comprise one or more electronic control units, processing units, computers, server units or the like of an off-board system arranged externally to a vehicle and being operably connectable to the vehicle.

15 The manifold configuration comprises an intake manifold arrangement and an exhaust manifold arrangement. The intake manifold arrangement and exhaust manifold arrangement are thus comprised in a manifold configuration of the engine. The intake manifold arrangement may be an intake manifold arrangement in accordance with the intake manifold arrangement 50 described
20 with reference to fig. 3. The exhaust manifold arrangement be an exhaust manifold arrangement in accordance with the exhaust manifold arrangement 60 described with reference to fig. 3.

The intake manifold arrangement is configured to distribute compressed air to the cylinders of the engine during engine operation.

25 The exhaust manifold arrangement is configured to distribute exhaust gas from the cylinders to the exhaust pipe system of the vehicle.

The manifold pressures are determined in the intake manifold arrangement in connection to individual cylinders and/or the exhaust manifold arrangement in connection to individual cylinders.

The control device 100 according to the present invention is thus configured to determine the manifold pressure in an intake manifold arrangement in connection to individual cylinders of an internal combustion engine and/or configured to determine the manifold pressure in an exhaust manifold arrangement in connection to individual cylinders of the internal combustion engine.

The manifold pressure in the intake manifold arrangement is the pressure of the compressed air configured to be distributed to the cylinders. The intake manifold pressure is arranged to be determined in the intake manifold arrangement in connection to the individual cylinders.

The manifold pressure in the exhaust manifold arrangement is the exhaust gas pressure of the exhaust gas configured to be distributed to from the cylinders to the exhaust gas pipe. The exhaust manifold pressure is arranged to be determined in the exhaust manifold arrangement in connection to the individual cylinders.

The control device 100 is configured to, for calibration, create a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value.

The control device 100 is further configured to store the thus created transfer functions for the engine cylinders.

The control device 100 is, during vehicle operation, configured to determine the manifold pressure in connection to the individual cylinders based upon

pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

According to an embodiment the control device 100, for calibration, for the intake manifold arrangement, is configured to detect the local manifold
5 pressure values in connection to each individual cylinder by means of local pressure sensors 111, 112, 113, 114, 115, 116 arranged in the intake manifold arrangement in connection to the respective cylinder. See also fig. 5a. Here six local pressure sensors are shown for a six cylinder engine. The local pressure sensors 111, 112, 113, 114, 115, 116 arranged in the intake manifold
10 arrangement may be comprised in a local pressure sensor arrangement 110 for the intake manifold arrangement.

The local pressure sensors 111, 112, 113, 114, 115, 116 are configured to detect the local pressure in connection to the respective cylinder of the engine for a range of crank angle values and a range of engine speed values.

15 The control device 100, for calibration, for the intake manifold arrangement, is further configured to detect the manifold reference pressure values by means of a reference pressure sensor arrangement 120 arranged in the intake manifold arrangement. If the reference pressure sensor arrangement, e.g. a reference pressure sensor, is arranged relatively close to one of the cylinders,
20 that reference pressure sensor may also function as the local pressure sensor for that cylinder and thus replace that local pressure sensor.

The reference pressure sensor arrangement 120 may comprise one or more pressure sensors. The reference pressure sensor arrangement 120 may comprise a reference pressure sensor 122 for detecting a reference pressure
25 in the intake manifold arrangement for calibration.

According to an embodiment, when detecting the pressure in the intake manifold arrangement by means of the reference pressure sensor arrangement 120 according to the present disclosure, a reference pressure sensor for each bank of the intake manifold arrangement is used.

The reference pressure sensor arrangement 120 may comprise one or more pressure sensors used for detecting pressure in the intake manifold arrangement for calibration. The reference pressure sensor arrangement 120 may comprise one or more pressure sensors used for detecting pressure in
5 the intake manifold arrangement during vehicle operation. The one or more sensors of the reference pressure sensor arrangement 120 configured to be used for calibration may be the same as the one or more sensors of the reference pressure sensor arrangement 120 configured to be used during vehicle operation and/or different sensors of the reference pressure sensor
10 arrangement.

The control device 100 is according to an embodiment operably connected to the reference pressure sensor arrangement 120. The system I may comprise the reference pressure sensor arrangement 120.

The reference pressure sensor arrangement 120 is configured to detect the
15 reference pressure in the intake manifold arrangement for the range of crank angle values and a range of engine speed values used for the local pressure sensors 111, 112, 113, 114, 115, 116.

The control device 100, for calibration, for the intake manifold arrangement, is configured to create a transfer function for each cylinder, the respective
20 transfer function comprising pressure coefficient values for a set of operation parameters comprising the range of crank angle values and range of engine speed values. Fig. 8 illustrates an example of such a transfer function.

Each pressure coefficient value is based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value of the
25 intake manifold arrangement. According to an embodiment of the control device each pressure coefficient value is based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based upon a determined heat capacity ratio and a determined Mach number of the intake manifold arrangement.

According to an embodiment the control device 100 is configured to determine the pressure coefficient values based upon a linearized pressure coefficient model. An embodiment of a linearized pressure coefficient model for the intake manifold arrangement is:

5

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

Here, LPC is the linearized pressure coefficient, γ is the heat capacity ratio, M_{∞} is the undisturbed or reference Mach number, which is based on the speed of sound, p is the local pressure in connection to a cylinder, and p_{∞} is the undisturbed or reference pressure.

The local pressure p in connection to a cylinder is thus provided for the respective cylinder from the local pressure sensors 111, 112, 113, 114, 115, 116, and the reference pressure p_{∞} is provided by the reference pressure sensor arrangement 120.

Other parameters which may be relevant in order to provide the linearized pressure coefficient model for the intake manifold arrangement are the cross sectional area/areas of the intake manifold arrangement, the undisturbed temperature in connection to the intake manifold arrangement, the gas constant of the gas in the intake manifold arrangement and the estimated mass motion velocity of the gas in the intake manifold arrangement.

The control device 100 is further configured to store the thus, for the intake manifold arrangement, created transfer functions for the engine cylinders.

The system I may comprise a storage device 130 for storing the created transfer functions for the engine cylinders. The storage device 130 may be any

suitable storage device such as an internal storage device arranged in the vehicle and/or an external storage device arranged externally to the vehicle.

The control device 100 may comprise or be operably connectable to the storage device 130 for storing the created transfer functions for the engine
5 cylinders.

The control device 100 is further configured to determine the manifold pressure in connection to the individual cylinders based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

- 10 The control device 100 is configured to, during vehicle operation, detect manifold reference pressure values in the intake manifold arrangement by means of a reference pressure sensor arrangement arranged in the intake manifold arrangement. The reference pressure sensor arrangement may be the same reference pressure sensor arrangement 120 used for calibration or
15 a pressure sensor arrangement of the same kind. The reference pressure sensor of the pressure sensor arrangement 120 configured to be used during vehicle operation may be the same reference pressure sensor, e.g. reference pressure sensor 122 or another reference pressure sensor, e.g. reference pressure sensor 124.
- 20 In the embodiment where the linearized pressure coefficient model for the intake manifold arrangement is used, i.e.:

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

- 25 the local pressure p in the intake manifold in connection to the respective cylinder for a range of crank angle values and a range of engine speed values

by the pressure coefficient values of the stored transfer functions for the that range of crank angle values and range of engine speed values and the corresponding detected manifold reference pressure values by using the linearized pressure coefficient model, the local pressure being the only
 5 unknown value:

$$p = \left(\frac{LPC \cdot \gamma \cdot M_{\infty}^2}{2} + 1 \right) \cdot p_{\infty}$$

See also fig. 8 and related text.

10 According to an embodiment the control device 100, for calibration, for the exhaust manifold arrangement, is configured to detect the local manifold pressure values in connection to each individual cylinder by means of local pressure sensors 141, 142, 143, 144, 145, 146 arranged in the exhaust manifold arrangement in connection to the respective cylinder. See also fig.
 15 5a. Here six local pressure sensors are shown for a six cylinder engine. The local pressure sensors 141, 142, 143, 144, 145, 146 arranged in the exhaust manifold arrangement may be comprised in a local pressure sensor arrangement 140 for the exhaust manifold arrangement.

The local pressure sensors 141, 142, 143, 144, 145, 146 are configured to
 20 detect the local pressure in connection to the respective cylinder of the engine for a range of crank angle values and a range of engine speed values.

The control device 100, for calibration, for the exhaust manifold arrangement, is further configured to detect the manifold reference pressure values by means of a reference pressure sensor arrangement 150 arranged in the
 25 exhaust manifold arrangement. If the reference pressure sensor arrangement, e.g. a reference pressure sensor, is arranged relatively close to one of the

cylinders, that reference pressure sensor may also function as the local pressure sensor for that cylinder and thus replace that local pressure sensor.

The reference pressure sensor arrangement 150 may comprise one or more pressure sensors. The reference pressure sensor arrangement 150 may
5 comprise a reference pressure sensor 152 for detecting a reference pressure in the exhaust manifold arrangement for calibration.

According to an embodiment, when detecting the pressure in the exhaust manifold arrangement by means of the reference pressure sensor arrangement 150 according to the present disclosure, a reference pressure
10 sensor for each bank of the exhaust manifold arrangement is used.

The reference pressure sensor arrangement 150 may comprise one or more pressure sensors used for detecting pressure in the exhaust manifold arrangement for calibration. The reference pressure sensor arrangement 150 may comprise one or more pressure sensors used for detecting pressure in
15 the exhaust manifold arrangement during vehicle operation. The one or more sensors of the reference pressure sensor arrangement 150 configured to be used for calibration may be the same as the one or more sensors of the reference pressure sensor arrangement 150 configured to be used during vehicle operation and/or different sensors of the reference pressure sensor
20 arrangement.

The control device 100 is according to an embodiment operably connected to the reference pressure sensor arrangement 150. The system I may comprise the reference pressure sensor arrangement 150.

The reference pressure sensor arrangement 150 is configured to detect the
25 reference pressure in the exhaust manifold arrangement for the range of crank angle values and a range of engine speed values used for the local pressure sensors 141, 142, 143, 144, 145, 146.

The control device 100, for calibration, for the exhaust manifold arrangement, is configured to create a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set of operation parameters comprising the range of crank angle values and range of engine speed values. Fig. 8 illustrates an example of such a transfer function.

Each pressure coefficient value is based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value of the exhaust manifold arrangement. According to an embodiment of the control device each pressure coefficient value is based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based upon a determined heat capacity ratio and a determined Mach number of the exhaust manifold arrangement.

According to an embodiment the control device 100 is configured to determine the pressure coefficient values based upon a linearized pressure coefficient model. An embodiment of a linearized pressure coefficient model for the exhaust manifold arrangement is:

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

Here, LPC is the linearized pressure coefficient, γ is the heat capacity ratio, M_{∞} is the undisturbed or reference Mach number, which is based on the speed of sound, p is the local pressure in connection to a cylinder, and p_{∞} is the undisturbed or reference pressure.

Here, for the exhaust manifold arrangement, the same parameters are relevant as for the intake manifold arrangement. However, the determination of the parameters may be different or parameters from the intake manifold may occasionally be used.

The local pressure p in connection to a cylinder is thus provided for the respective cylinder from the local pressure sensors 141, 142, 143, 144, 145, 146, and the reference pressure p_{∞} is provided by the reference pressure sensor arrangement 150.

- 5 Other parameters which may be relevant in order to provide the linearized pressure coefficient model for the exhaust manifold arrangement are the cross sectional area/areas of the exhaust manifold arrangement, the undisturbed temperature in connection to the exhaust manifold arrangement, the gas constant of the gas in the exhaust manifold arrangement and the estimated
- 10 mass motion velocity of the gas in the exhaust manifold arrangement.

The control device 100 is further configured to store the thus, for the exhaust manifold arrangement, created transfer functions for the engine cylinders.

- The system I may comprise a storage device 130 for storing the created transfer functions for the engine cylinders. The storage device 130 may be any
- 15 suitable storage device such as an internal storage device arranged in the vehicle and/or an external storage device arranged externally to the vehicle. The storage device 130 may be the same storage device as for storing created transfer functions for the intake manifold arrangement or another storage device.

- 20 The control device 100 may comprise or be operably connectable to the storage device 130 for storing the created transfer functions for the engine cylinders.

- The control device 100 is further configured to, during vehicle, operation determine the manifold pressure in connection to the individual cylinders
- 25 based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

The control device 100 is configured to, during vehicle operation, detect manifold reference pressure values in the exhaust manifold arrangement by

means of a reference pressure sensor arrangement arranged in the exhaust manifold arrangement. The reference pressure sensor arrangement may be the same reference pressure sensor arrangement 150 used for calibration or a pressure sensor arrangement of the same kind. The reference pressure
 5 sensor of the pressure sensor arrangement 150 configured to be used during vehicle operation may be the same reference pressure sensor, e.g. reference pressure sensor 152 or another reference pressure sensor, e.g. reference pressure sensor 154.

In the embodiment where the linearized pressure coefficient model for the
 10 exhaust manifold arrangement is used, i.e.:

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

the local pressure p in the exhaust manifold in connection to the respective
 15 cylinder for a range of crank angle values and a range of engine speed values by the pressure coefficient values of the stored transfer functions for the that range of crank angle values and range of engine speed values and the corresponding detected manifold reference pressure values by using the linearized pressure coefficient model, the local pressure being the only
 20 unknown value:

$$p = \left(\frac{LPC \cdot \gamma \cdot M_{\infty}^2}{2} + 1 \right) \cdot p_{\infty}$$

See also fig. 8 and related text.

According to an embodiment of the invention, the control device 100 is, via a link 111a, during calibration, operably connected to the local pressure sensor 111. According to an embodiment of the invention, the control device 100 is via the link 111a arranged to receive signals from the local pressure sensor
5 111 representing data about local manifold pressure in the intake manifold arrangement in connection to a first engine cylinder for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 112a, during calibration, operably connected to the local pressure sensor
10 112. According to an embodiment of the invention, the control device 100 is via the link 112a arranged to receive signals from the local pressure sensor 112 representing data about local manifold pressure in the intake manifold arrangement in connection to a second engine cylinder for a range of crank angle values and a range of engine speed values.

15 According to an embodiment of the invention, the control device 100 is, via a link 113a, during calibration, operably connected to the local pressure sensor 113. According to an embodiment of the invention, the control device 100 is via the link 113a arranged to receive signals from the local pressure sensor 113 representing data about local manifold pressure in the intake manifold
20 arrangement in connection to a third engine cylinder for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 114a, during calibration, operably connected to the local pressure sensor 114. According to an embodiment of the invention, the control device 100 is
25 via the link 114a arranged to receive signals from the local pressure sensor 114 representing data about local manifold pressure in the intake manifold arrangement in connection to a fourth engine cylinder for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 115a, during calibration, operably connected to the local pressure sensor 115. According to an embodiment of the invention, the control device 100 is via the link 115a arranged to receive signals from the local pressure sensor

5 115 representing data about local manifold pressure in the intake manifold arrangement in connection to a fifth engine cylinder for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 116a, during calibration, operably connected to the local pressure sensor

10 116. According to an embodiment of the invention, the control device 100 is via the link 116a arranged to receive signals from the local pressure sensor 116 representing data about local manifold pressure in the intake manifold arrangement in connection to a sixth engine cylinder for a range of crank angle values and a range of engine speed values.

15 According to an embodiment of the invention, the control device 100 is, via a link 120a, during calibration, operably connected to the reference pressure sensor arrangement 120. According to an embodiment of the invention, the control device 100 is via the link 120a arranged to receive signals from the reference pressure sensor arrangement 120 representing data about manifold

20 reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 122a, during calibration, operably connected to the reference pressure sensor 122. According to an embodiment of the invention, the control device

25 100 is via the link 122a arranged to receive signals from the reference pressure sensor 122 representing data about manifold reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 124a, during calibration, operably connected to the reference pressure sensor 124. According to an embodiment of the invention, the control device 100 is via the link 124a arranged to receive signals from the reference pressure
5 sensor 124 representing data about manifold reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

The control device 100, for calibration, for the intake manifold arrangement, is arranged to process the data about local manifold pressure in the intake
10 manifold arrangement in connection to the different cylinders and the data about manifold reference pressure in the intake manifold arrangement so as to determine pressure coefficient values based upon the ratio between local manifold pressure values and a corresponding manifold reference pressure values. The control device 100 is further configured to create a transfer
15 function for each cylinder, the respective transfer function comprising the thus determined pressure coefficient values for a set of operation parameters comprising the range of crank angle values and the range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a
20 link 130a, operably connected to the storage device 130. According to an embodiment of the invention, the control device 100 is via the link 130a arranged to send signals to the storage device 130 representing data about the created transfer functions for the engine cylinders for the intake manifold arrangement.

25 According to an embodiment of the invention, the control device 100 is, via a link 120a, during vehicle operation, operably connected to the reference pressure sensor arrangement 120. According to an embodiment of the invention, the control device 100 is via the link 120a arranged to receive signals from the reference pressure sensor arrangement 120 representing data about

manifold reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 122a, during vehicle operation, operably connected to the reference pressure sensor 122. According to an embodiment of the invention, the control device 100 is via the link 122a arranged to receive signals from the reference pressure sensor 122 representing data about manifold reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 124a, during vehicle operation, operably connected to the reference pressure sensor 124. According to an embodiment of the invention, the control device 100 is via the link 124a arranged to receive signals from the reference pressure sensor 124 representing data about manifold reference pressure in the intake manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 130b, during vehicle operation, operably connected to the storage device 130. According to an embodiment of the invention, the control device 100 is via the link 130b arranged to receive signals from the storage device 130 representing data about the stored transfer functions for the engine cylinders for the intake manifold arrangement.

The control device 100 is configured to process the data about the transfer functions and data about, during vehicle operation, detected manifold reference pressure values so as to determine the manifold pressure in connection to the individual cylinders for the intake manifold arrangement.

According to an embodiment of the invention, the control device 100 is, via a link 141a, during calibration, operably connected to the local pressure sensor 141. According to an embodiment of the invention, the control device 100 is

via the link 141a arranged to receive signals from the local pressure sensor 141 representing data about local manifold pressure in the exhaust manifold arrangement in connection to a first engine cylinder for a range of crank angle values and a range of engine speed values.

- 5 According to an embodiment of the invention, the control device 100 is, via a link 142a, during calibration, operably connected to the local pressure sensor 142. According to an embodiment of the invention, the control device 100 is via the link 142a arranged to receive signals from the local pressure sensor 142 representing data about local manifold pressure in the exhaust manifold
10 arrangement in connection to a second engine cylinder for a range of crank angle values and a range of engine speed values.

- According to an embodiment of the invention, the control device 100 is, via a link 143a, during calibration, operably connected to the local pressure sensor 143. According to an embodiment of the invention, the control device 100 is
15 via the link 143a arranged to receive signals from the local pressure sensor 143 representing data about local manifold pressure in the exhaust manifold arrangement in connection to a third engine cylinder for a range of crank angle values and a range of engine speed values.

- According to an embodiment of the invention, the control device 100 is, via a
20 link 144a, during calibration, operably connected to the local pressure sensor 144. According to an embodiment of the invention, the control device 100 is via the link 144a arranged to receive signals from the local pressure sensor 144 representing data about local manifold pressure in the exhaust manifold arrangement in connection to a fourth engine cylinder for a range of crank
25 angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 145a, during calibration, operably connected to the local pressure sensor 145. According to an embodiment of the invention, the control device 100 is via the link 145a arranged to receive signals from the local pressure sensor

145 representing data about local manifold pressure in the exhaust manifold arrangement in connection to a fifth engine cylinder for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a
5 link 146a, during calibration, operably connected to the local pressure sensor 146. According to an embodiment of the invention, the control device 100 is via the link 146a arranged to receive signals from the local pressure sensor 146 representing data about local manifold pressure in the exhaust manifold arrangement in connection to a sixth engine cylinder for a range of crank angle
10 values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 150a, during calibration, operably connected to the reference pressure sensor arrangement 150. According to an embodiment of the invention, the control device 100 is via the link 150a arranged to receive signals from the
15 reference pressure sensor arrangement 150 representing data about manifold reference pressure in the exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 152a, during calibration, operably connected to the reference pressure
20 sensor 152. According to an embodiment of the invention, the control device 100 is via the link 152a arranged to receive signals from the reference pressure sensor 152 representing data about manifold reference pressure in the exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

25 According to an embodiment of the invention, the control device 100 is, via a link 154a, during calibration, operably connected to the reference pressure sensor 154. According to an embodiment of the invention, the control device 100 is via the link 154a arranged to receive signals from the reference pressure sensor 154 representing data about manifold reference pressure in the

exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

The control device 100, for calibration, for the exhaust manifold arrangement, is arranged to process the data about local manifold pressure in the exhaust manifold arrangement in connection to the different cylinders and the data about manifold reference pressure in the exhaust manifold arrangement so as to determine pressure coefficient values based upon the ratio between local manifold pressure values and a corresponding manifold reference pressure values. The control device 100 is further configured to create a transfer function for each cylinder, the respective transfer function comprising the thus determined pressure coefficient values for a set of operation parameters comprising the range of crank angle values and the range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 130a, operably connected to the storage device 130. According to an embodiment of the invention, the control device 100 is via the link 130a arranged to send signals to the storage device 130 representing data about the created transfer functions for the engine cylinders for the exhaust manifold arrangement.

According to an embodiment of the invention, the control device 100 is, via a link 150a, during vehicle operation, operably connected to the reference pressure sensor arrangement 150. According to an embodiment of the invention, the control device 100 is via the link 150a arranged to receive signals from the reference pressure sensor arrangement 150 representing data about manifold reference pressure in the exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

According to an embodiment of the invention, the control device 100 is, via a link 152a, during vehicle operation, operably connected to the reference pressure sensor 152. According to an embodiment of the invention, the control

device 100 is via the link 152a arranged to receive signals from the reference pressure sensor 152 representing data about manifold reference pressure in the exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

- 5 According to an embodiment of the invention, the control device 100 is, via a link 154a, during vehicle operation, operably connected to the reference pressure sensor 154. According to an embodiment of the invention, the control device 100 is via the link 154a arranged to receive signals from the reference pressure sensor 154 representing data about manifold reference pressure in
10 the exhaust manifold arrangement for a range of crank angle values and a range of engine speed values.

- According to an embodiment of the invention, the control device 100 is, via a link 130b, during vehicle operation, operably connected to the storage device 130. According to an embodiment of the invention, the control device 100 is
15 via the link 130b arranged to receive signals from the storage device 130 representing data about the stored transfer functions for the engine cylinders for the exhaust manifold arrangement.

- The control device 100 is configured to process the data about the transfer functions and data about, during vehicle operation, detected manifold
20 reference pressure values so as to determine the manifold pressure in connection to the individual cylinders for the exhaust manifold arrangement.

Fig. 5a schematically illustrates a manifold configuration M of the engine in fig. 3 during calibration according to an embodiment of the present disclosure.

- In fig. 5a the intake manifold arrangement 50 and the exhaust manifold
25 arrangement 60 of the manifold configuration M are illustrated. Further the cylinders C1, C2, C3, C4, C5, C6 of the engine in connection to the manifold configuration M are illustrated.

As described with reference to fig. 4, a control device 100 according to the present invention, also shown in fig. 5a, is configured to determine the manifold pressure in the intake manifold arrangement 50 in connection to individual cylinders C1, C2, C3, C4, C5, C6 of the internal combustion engine and/or
5 configured to determine the manifold pressure in an exhaust manifold arrangement 60 in connection to individual cylinders C1, C2, C3, C4, C5, C6 of the internal combustion engine.

The manifold pressure in the intake manifold arrangement 50 is the pressure of the compressed air A4 configured to be distributed to the cylinders C1, C2,
10 C3, C4, C5, C6. The manifold pressure in the exhaust manifold arrangement 60 is the exhaust gas pressure of the exhaust gas G1 configured to be distributed to from the cylinders C1, C2, C3, C4, C5, C6 to the exhaust gas pipe.

For calibration, for the intake manifold arrangement, the local manifold
15 pressure values are detected in connection to each individual cylinder C1, C2, C3, C4, C5, C6 by means of local pressure sensors 111, 112, 113, 114, 115, 116 arranged in the intake manifold arrangement 50 in connection to the respective cylinder C1, C2, C3, C4, C5, C6 for a range of crank angle values and a range of engine speed values.

20 For calibration, for the intake manifold arrangement 50, the manifold reference pressure values are detected by means of a reference pressure sensor arrangement 120 arranged in the intake manifold arrangement for the range of crank angle values and range of engine speed values used for the local pressure sensors 111, 112, 113, 114, 115, 116. The reference pressure sensor
25 arrangement 120 is according to this embodiment one reference pressure sensor.

As described in fig. 4 the control device 100, for calibration, for the intake manifold arrangement 50, is configured to create a transfer function for each cylinder C1, C2, C3, C4, C5, C6, the respective transfer function comprising

pressure coefficient values for a set of operation parameters comprising the range of crank angle values and range of engine speed values. The thus created transfer functions are stored in a storage device.

5 For calibration, for the exhaust manifold arrangement 60, the local manifold pressure values are detected in connection to each individual cylinder C1, C2, C3, C4, C5, C6 by means of local pressure sensors 141, 142, 143, 144, 145, 146 arranged in the exhaust manifold arrangement in connection to the respective cylinder C1, C2, C3, C4, C5, C6 for a range of crank angle values and a range of engine speed values.

10 For calibration, for the exhaust manifold arrangement 60, the manifold reference pressure values are detected by means of a reference pressure sensor arrangement 150 arranged in the exhaust manifold arrangement for the range of crank angle values and range of engine speed values used for the local pressure sensors 141, 142, 143, 144, 145, 146. The reference pressure
15 sensor arrangement 150 is according to this embodiment one reference pressure sensor.

As described in fig. 4 the control device 100, for calibration, for the exhaust manifold arrangement 60, is configured to create a transfer function for each cylinder C1, C2, C3, C4, C5, C6, the respective transfer function comprising
20 pressure coefficient values for a set of operation parameters comprising the range of crank angle values and range of engine speed values. The thus created transfer functions are stored in a storage device.

Fig. 5b schematically illustrates the manifold configuration M in fig. 5a during vehicle operation according to an embodiment of the present disclosure.

25 In fig. 5b the intake manifold arrangement 50 and the exhaust manifold arrangement 60 of the manifold configuration M are illustrated. Further the cylinders C1, C2, C3, C4, C5, C6 of the engine in connection to the manifold configuration M are illustrated.

The control device 100 is further configured to, during vehicle operation, for the intake manifold arrangement 50, determine the manifold pressure in connection to the individual cylinders C1, C2, C3, C4, C5, C6 based upon pressure coefficient values of the thus stored transfer functions and
5 corresponding detected manifold reference pressure values.

The control device 100 is further configured to, during vehicle operation, for the exhaust manifold arrangement 60, determine the manifold pressure in connection to the individual cylinders C1, C2, C3, C4, C5, C6 based upon pressure coefficient values of the thus stored transfer functions and
10 corresponding detected manifold reference pressure values.

During vehicle operation only the reference pressure sensor arrangement 120 is required in order to determine the intake manifold pressure in connection to the individual cylinders C1, C2, C3, C4, C5, C6. During vehicle operation only the reference pressure sensor arrangement 150 is required in order to
15 determine the intake manifold pressure in connection to the individual cylinders C1, C2, C3, C4, C5, C6.

Fig. 6 schematically illustrates a flowchart of a method M1 performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine according
20 to an embodiment of the present disclosure.

The manifold configuration comprises an intake manifold arrangement and an exhaust manifold arrangement. The manifold pressures are determined in the intake manifold arrangement in connection to individual cylinders and/or the exhaust manifold arrangement in connection to individual cylinders.

25 According to the embodiment the method M1 performed by a control for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine comprises a step S1. In this step, for calibration, a transfer function for each cylinder is created, the respective transfer function comprising pressure coefficient values for a set of

operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis
 5 for the creation of each transfer function, each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value.

According to the embodiment the method M1 comprises a step S2. In this step the thus created transfer functions for the engine cylinders are stored. Storage
 10 of the transfer functions may be performed with a storage device, e.g. a storage device 130 as described with reference to fig. 4.

According to the embodiment the method M1 comprises a step S3. In this step, during vehicle operation, the manifold pressure is determined in connection to the individual cylinders based upon pressure coefficient values of the thus
 15 stored transfer functions and corresponding detected manifold reference pressure values.

According to an embodiment of the method each pressure coefficient value are based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based
 20 upon a determined heat capacity ratio and a determined Mach number.

According to an embodiment of the method the pressure coefficient values are determined based upon a linearized pressure coefficient model. The linearized pressure coefficient model is according to an embodiment the model described with reference to fig. 4, i.e.:

25

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

According to an embodiment of the method, for calibration, for the inlet manifold arrangement, the local manifold pressure values in connection to each individual cylinder are detected by means of local pressure sensors arranged in the inlet manifold arrangement in connection to the respective
5 cylinder, and the manifold reference pressure values are detected by means of a reference pressure sensor arranged in the inlet manifold arrangement.

According to an embodiment of the method, for calibration, for the exhaust manifold arrangement, the local manifold pressure values in connection to each individual cylinder are detected by means of local pressure sensors
10 arranged in the exhaust manifold arrangement in connection to the respective cylinder, and the manifold reference pressure values are detected by means of a reference pressure sensor arranged in the exhaust manifold arrangement.

According to an embodiment of the method, during vehicle operation, for the inlet manifold arrangement, the detected manifold reference pressure values
15 are detected by means of a reference pressure sensor arranged in the inlet manifold arrangement.

According to an embodiment of the method, during vehicle operation, for the exhaust manifold arrangement, the detected manifold reference pressure values are detected by means of a reference pressure sensor arranged in the
20 exhaust manifold arrangement.

The method M1 according to the present invention thus determines the manifold pressure in the intake manifold arrangement in connection to individual cylinders of an internal combustion engine and/or determines the manifold pressure in the exhaust manifold arrangement in connection to
25 individual cylinders of the internal combustion engine.

The method M1 performed by a control device for determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine may be performed by the control device 100 described above with reference to fig. 4.

Fig. 7 schematically illustrates pressure coefficients for an engine cycle for a certain engine speed and various loads.

The example in fig. 7 shows the result using pressure coefficients determined for cylinder 1 for the intake manifold arrangement, e.g. cylinder C1 in fig. 3, 4 and 5a-b, for an engine speed of 1000 rpm and for 100% load, 75% load, 50% load and 25% load.

In the example in fig. 7 the linearized pressure coefficient model for the intake manifold arrangement has been used for determining the pressure coefficients, i.e.:

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

As can be seen in fig. 7, by thus basing each pressure coefficient value, here linearized pressure coefficient value, upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value a load independence is obtained, thus saving computational time and computational space.

Thus, in the example in fig. 7, by using the linearized pressure coefficient model for the intake manifold arrangement for an engine speed of 1000 rpm the function of linearized pressure coefficients for an engine cycle, i.e. 720 crank angles, for 100% load, 75% load, 50% load and 25% load essentially correspond to each other, showing a load independence. This load independence is due to the ratio between a local manifold pressure value p and a corresponding manifold reference pressure value p_{∞} .

Fig. 7 depicts the load independency of the linearized pressure coefficient for various loads and constitutes an example for cylinder 1 and 1000 rpm. However, this load independency is observed within all the engine speeds and cylinders. This load independency facilitates easier creation of the transfer

functions that are used for the estimation of the local pressures, see fig. 8 for example of transfer function.

Fig. 8 schematically illustrates a transfer function T for a cylinder comprising linearized pressure coefficient values LPC for range of crank angle values and
5 a range of engine speed values.

The transfer function according to this example is a map. The transfer function according to the present disclosure may be any suitable transfer function such as an equation, a line or a variable.

The transfer function T is intended to be used for calibration as described
10 above with reference to e.g. fig. 4 and 6.

The example in fig. 8 shows the transfer function T for one cylinder, e.g. cylinder 1, for the intake manifold arrangement. The transfer function T comprises pressure coefficient values for a set of operation parameters comprising a range of crank angle values and a range of engine speed values.
15 Here the range of crank angles is one engine cycle, e.g. 720 degrees for a six cylinder engine in accordance with fig. 2 and 3. Here the engine speed values ranges from 600 rpm to 2400 rpm.

In the example in fig. 8 the linearized pressure coefficient model for the intake manifold arrangement has been used for determining the pressure
20 coefficients, i.e.:

$$LPC = \frac{2}{\gamma \cdot M_{\infty}^2} \cdot \left(\frac{p}{p_{\infty}} - 1 \right)$$

The intake manifold pressure in connection to that individual cylinder, e.g. cylinder 1, is determined based upon the linearized pressure coefficient values
25 of the thus stored transfer function T and corresponding detected manifold reference pressure values as described above with reference to e.g. fig. 4.

The load independency due to the ratio between a local manifold pressure value and a corresponding manifold reference pressure, here illustrated with linearized pressure coefficient model, is the key tool that is used for the creation of the transfer functions. Due to this load independency the transfer function, e.g. experimental maps, become dependent only to engine speed and crank angle degrees.

With reference to figure 9, a diagram of a computer 500/apparatus 500 is shown. The control device 100 described with reference to fig. 4 may according to an embodiment comprise apparatus 500. Apparatus 500 comprises a non-volatile memory 520, a data processing device 510 and a read/write memory 550. Non-volatile memory 520 has a first memory portion 530 wherein a computer program, such as an operating system, is stored for controlling the function of apparatus 500. Further, apparatus 500 comprises a bus controller, a serial communication port, I/O-means, an A/D-converter, a time date entry and transmission unit, an event counter and an interrupt controller (not shown). Non-volatile memory 520 also has a second memory portion 540.

A computer program P is provided comprising routines determining manifold pressure in a manifold configuration in connection to individual cylinders of an internal combustion engine. The manifold configuration comprises an intake manifold arrangement and an exhaust manifold arrangement, the manifold pressures being determined in the intake manifold arrangement in connection to individual cylinders and/or the exhaust manifold arrangement in connection to individual cylinders.

The program P comprises routines for, for calibration, creating a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function,

each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value. The program P comprises routines storing the thus created transfer functions for the engine cylinders. The program P comprises routines for
5 during vehicle operation, determining the manifold pressure in connection to the individual cylinders based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

Each pressure coefficient value is based upon a ratio between a local manifold
10 pressure value and a corresponding manifold reference pressure value and is further based upon a determined heat capacity ratio and a determined Mach number. The pressure coefficient values are determined based upon a linearized pressure coefficient model.

The computer program P may be stored in an executable manner or in a
15 compressed condition in a separate memory 560 and/or in read/write memory 550.

When it is stated that data processing device 510 performs a certain function it should be understood that data processing device 510 performs a certain part of the program which is stored in separate memory 560, or a certain part
20 of the program which is stored in read/write memory 550.

Data processing device 510 may communicate with a data communications port 599 by means of a data bus 515. Non-volatile memory 520 is adapted for communication with data processing device 510 via a data bus 512. Separate memory 560 is adapted for communication with data processing device 510
25 via a data bus 511. Read/write memory 550 is adapted for communication with data processing device 510 via a data bus 514. To the data communications port 599 e.g. the links connected to the control unit 100 may be connected.

When data is received on data port 599 it is temporarily stored in second memory portion 540. When the received input data has been temporarily

stored, data processing device 510 is set up to perform execution of code in a manner described above. The signals received on data port 599 may be used by apparatus 500 for calibration, creating a transfer function for each cylinder, the respective transfer function comprising pressure coefficient values for a set
5 of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value being
10 based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value. The signals received on data port 599 may be used by apparatus 500 for storing the thus created transfer functions for the engine cylinders. The signals received on data port 599 may be used by apparatus 500 for during vehicle operation, determining
15 the manifold pressure in connection to the individual cylinders based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

Each pressure coefficient value is based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and is
20 further based upon a determined heat capacity ratio and a determined Mach number. The pressure coefficient values are determined based upon a linearized pressure coefficient model.

Parts of the methods described herein may be performed by apparatus 500 by means of data processing device 510 running the program stored in separate
25 memory 560 or read/write memory 550. When apparatus 500 runs the program, parts of the methods described herein are executed.

The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms
30 disclosed. Obviously, many modifications and variations will be apparent to

practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are

5 suited to the particular use contemplated.

CLAIMS

1. A method (M1) performed by a control device (100) for determining manifold pressure in a manifold configuration (M) in connection to individual cylinders (C1, C2, C3, C4, C5, C6) of an internal combustion engine (E), the
5 manifold configuration (M) comprising an intake manifold arrangement (50) and an exhaust manifold arrangement (60), the manifold pressures being determined in the intake manifold arrangement (50) in connection to individual cylinders (C1, C2, C3, C4, C5, C6) and/or the exhaust manifold arrangement (60) in connection to individual cylinders (C1, C2, C3, C4, C5, C6), the method
10 comprising the steps of:
- for calibration, creating (S1) a transfer function (T) for each cylinder, the respective transfer function comprising pressure coefficient values (LPC) for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to
15 an individual cylinder (C1, C2, C3, C4, C5, C6) and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value (LPC) being based upon a ratio between a local manifold pressure value and a corresponding manifold reference
20 pressure value;
 - storing (S2) the thus created transfer functions for the engine cylinders; and,
 - during vehicle operation, determining (S3) the manifold pressure in connection to the individual cylinders (C1, C2, C3, C4, C5, C6) based upon
25 pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.
2. The method according to claim 1, each pressure coefficient value being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based
30 upon a determined heat capacity ratio and a determined Mach number.

3. The method according to claim 1 or 2, wherein the pressure coefficient values (LPC) are determined based upon a linearized pressure coefficient model.
4. The method according to any of claims 1-3, wherein, for calibration, for the
5 intake manifold arrangement (50), the local manifold pressure values in connection to each individual cylinder are detected by means of local pressure sensors (111, 112, 113, 114, 115, 116) arranged in the intake manifold arrangement in connection to the respective cylinder (C1, C2, C3, C4, C5, C6), and the manifold reference pressure values are detected by means of a
10 reference pressure sensor arrangement (120) arranged in the intake manifold arrangement (50).
5. The method according to any of claims 1-4, wherein, for calibration, for the exhaust manifold arrangement (60), the local manifold pressure values in connection to each individual cylinder (C1, C2, C3, C4, C5, C6) are detected
15 by means of local pressure sensors (141, 142, 143, 144, 145, 146) arranged in the exhaust manifold arrangement (60) in connection to the respective cylinder (C1, C2, C3, C4, C5, C6), and the manifold reference pressure values are detected by means of a reference pressure sensor arrangement (150) arranged in the exhaust manifold arrangement (60).
- 20 6. The method according to any of claims 1-5, wherein, during vehicle operation, for the intake manifold arrangement (50), the detected manifold reference pressure values are detected by means of a reference pressure sensor arrangement (120) arranged in the intake manifold arrangement (50).
7. The method according to any of claims 1-6, wherein, during vehicle
25 operation, for the exhaust manifold arrangement (60), the detected manifold reference pressure values are detected by means of a reference pressure sensor arrangement (150) arranged in the exhaust manifold arrangement.
8. A control device for determining manifold pressure in a manifold configuration (M) in connection to individual cylinders (C1, C2, C3, C4, C5, C6)

of an internal combustion engine (E), the manifold configuration (M) comprising an intake manifold arrangement (50) and an exhaust manifold arrangement (60), the manifold pressures being determined in the intake manifold arrangement (50) in connection to individual cylinders (C1, C2, C3, C4, C5, C6) and/or the exhaust manifold arrangement (60) in connection to individual cylinders (C1, C2, C3, C4, C5, C6), the control device being configured to:

- for calibration, create a transfer function (T) for each cylinder (C1, C2, C3, C4, C5, C6), the respective transfer function comprising pressure coefficient values (LPC) for a set of operation parameters comprising a range of crank angle values and a range of engine speed values, local manifold pressure values in connection to an individual cylinder and a manifold reference pressure value being detected for the range of crank angle values and a range of engine speed values as a basis for the creation of each transfer function, each pressure coefficient value (LPC) being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value;
- store the thus created transfer functions for the engine cylinders (C1, C2, C3, C4, C5, C6); and,
- during vehicle operation, determine the manifold pressure in connection to the individual cylinders (C1, C2, C3, C4, C5, C6) based upon pressure coefficient values of the thus stored transfer functions and corresponding detected manifold reference pressure values.

9. The control device according to claim 8, each pressure coefficient value (LPC) being based upon a ratio between a local manifold pressure value and a corresponding manifold reference pressure value and further being based upon a determined heat capacity ratio and a determined Mach number.

10. The control device according to claim 8 or 9, wherein the control device (100) is configured to determine the pressure coefficient values (LPC) based upon a linearized pressure coefficient model.

11. The control device according to any of claims 8-10, wherein, for calibration, for the intake manifold arrangement (50), the control device (100) is configured to detect the local manifold pressure values in connection to each individual cylinder (C1, C2, C3, C4, C5, C6) by means of local pressure sensors (111, 112, 113, 114, 115, 116) arranged in the intake manifold arrangement (50) in connection to the respective cylinder, and wherein the control device (100) is configured to detect the manifold reference pressure values by means of a reference pressure sensor arrangement (120) arranged in the intake manifold arrangement (50).

12. The control device according to any of claims 8-10, wherein, for calibration, for the exhaust manifold arrangement (60), the control device (100) is configured to detect the local manifold pressure values in connection to each individual cylinder (C1, C2, C3, C4, C5, C6) by means of local pressure sensors (141, 142, 143, 144, 145, 146) arranged in the exhaust manifold arrangement (60) in connection to the respective cylinder, and wherein the control device (100) is configured to detect the manifold reference pressure values by means of a reference pressure sensor arrangement (150) arranged in the exhaust manifold arrangement (150).

13. The control device according to any of claims 8-12, wherein, during vehicle operation, for the intake manifold arrangement (50), the control device (100) is configured to detect manifold reference pressure values by means of a reference pressure sensor arrangement (120) arranged in the intake manifold arrangement (50).

14. The control device according to any of claims 8-12, wherein, during vehicle operation, for the exhaust manifold arrangement (60), the control device (100) is configured to detect manifold reference pressure values by means of a reference pressure sensor arrangement (150) arranged in the exhaust manifold arrangement (50).

15. A vehicle (1) comprising a control device (100) according to any of claims 8-14.

5 16. A computer program (P) for determining manifold pressure in a manifold configuration (M) in connection to individual cylinders of an internal combustion engine (E), said computer program (P) comprising program code which, when run on an control device (100) or another computer (500) connected to the control device (100), causes the control device to perform the steps according to claim 1-7.

10 17. A computer readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the method according to anyone of claims 1-7.

1/6

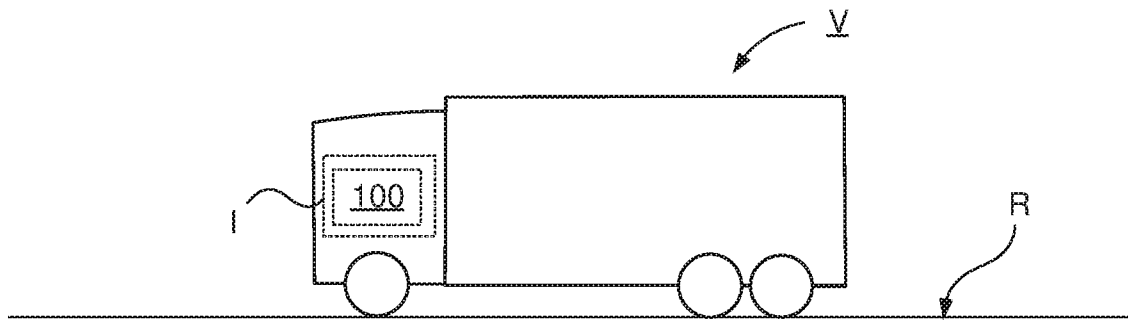


Fig. 1

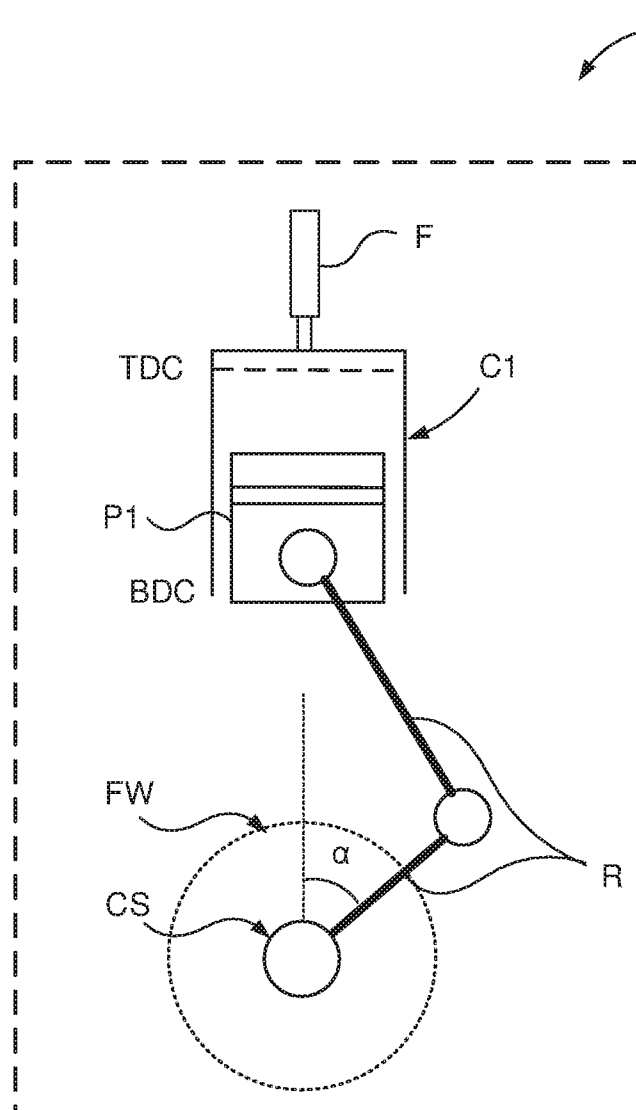


Fig. 2

2/6

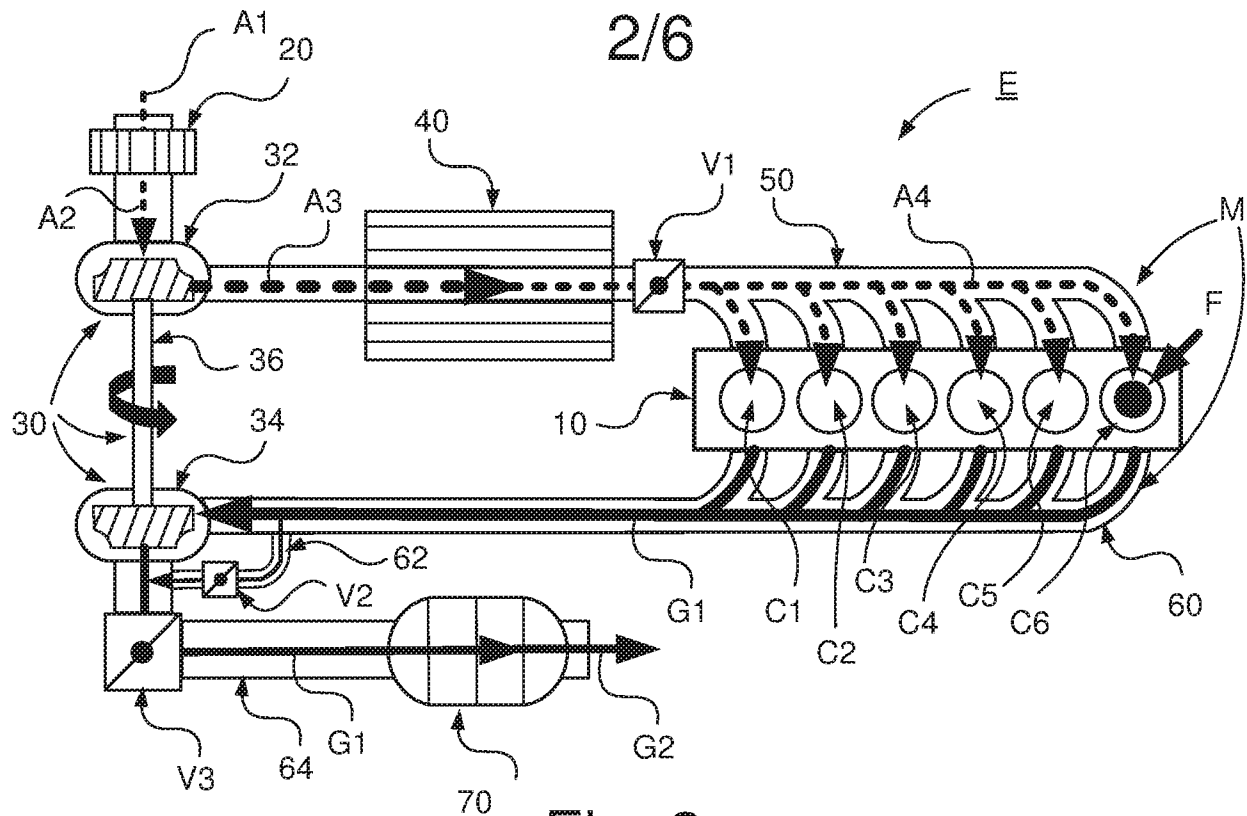


Fig. 3

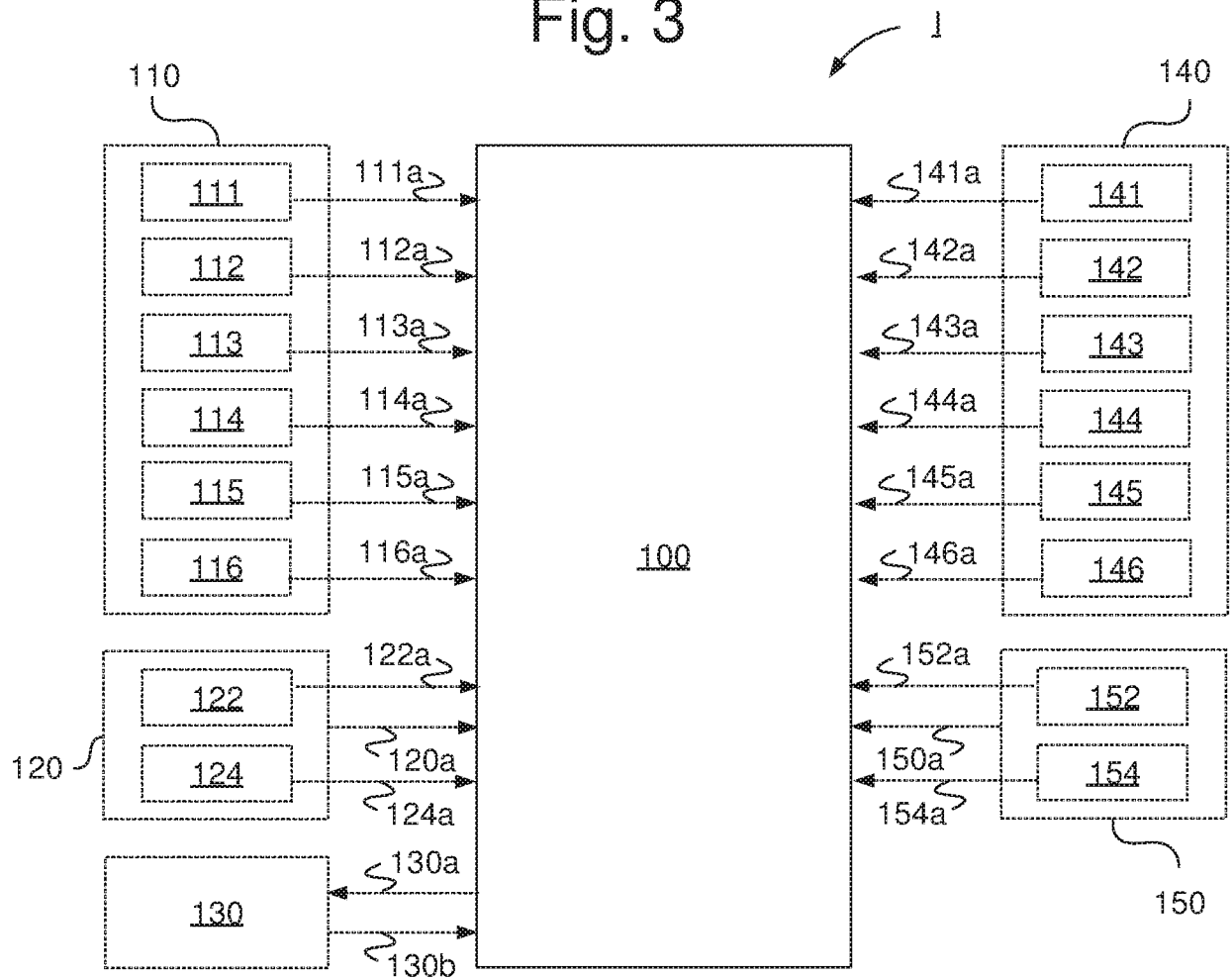


Fig. 4

3/6

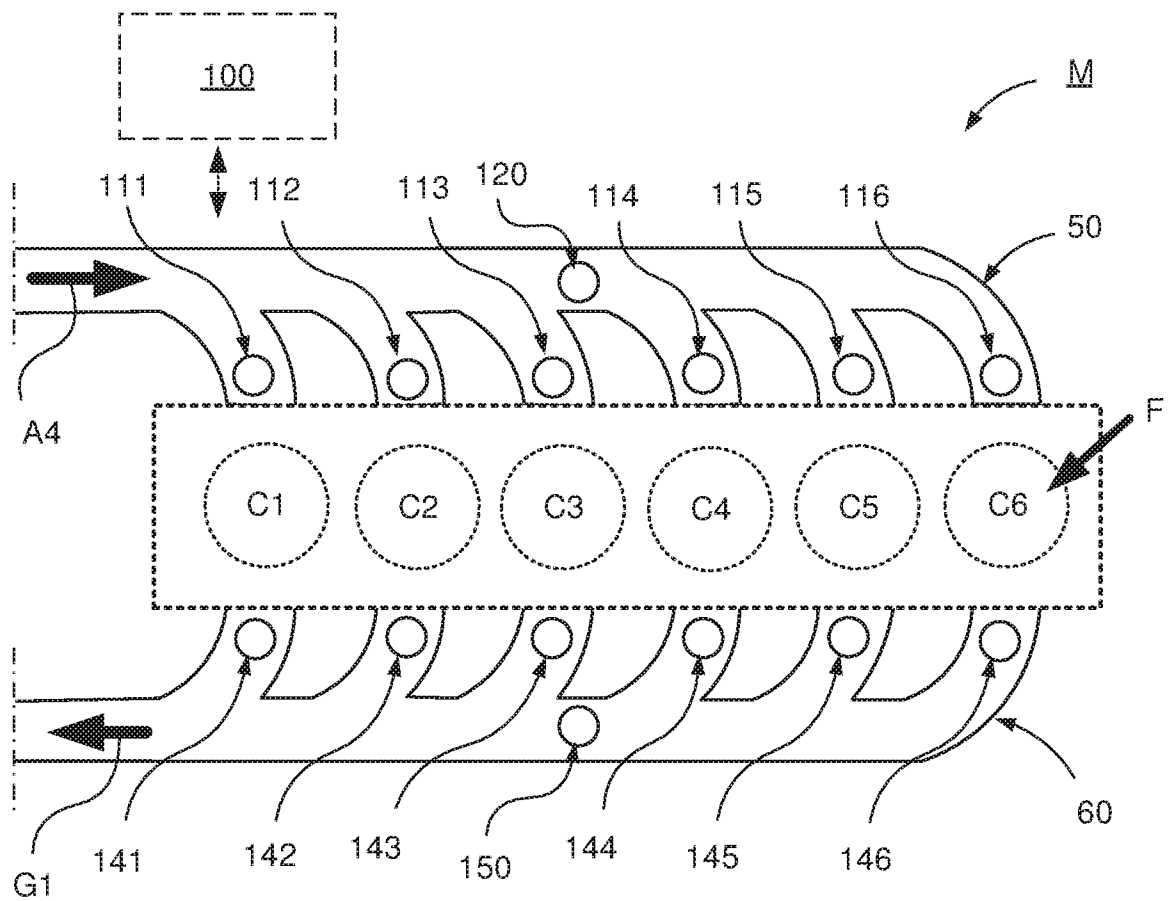


Fig. 5a

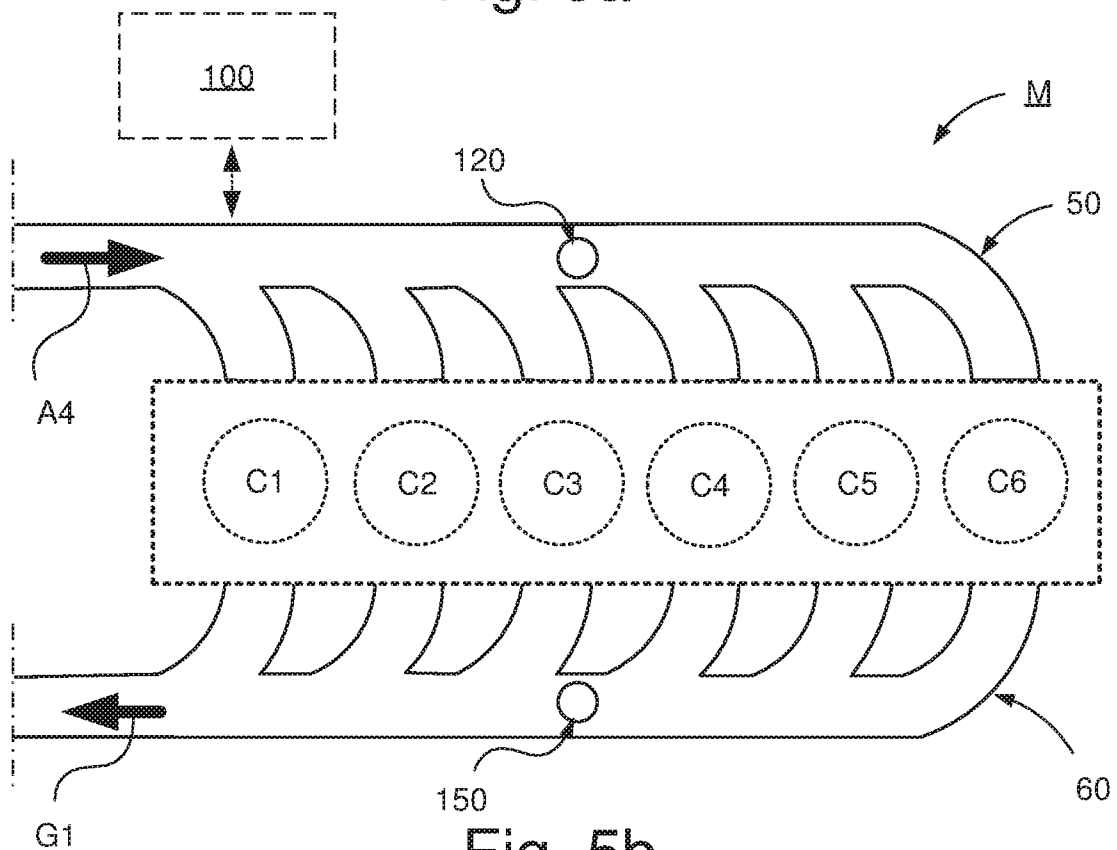


Fig. 5b

4/6

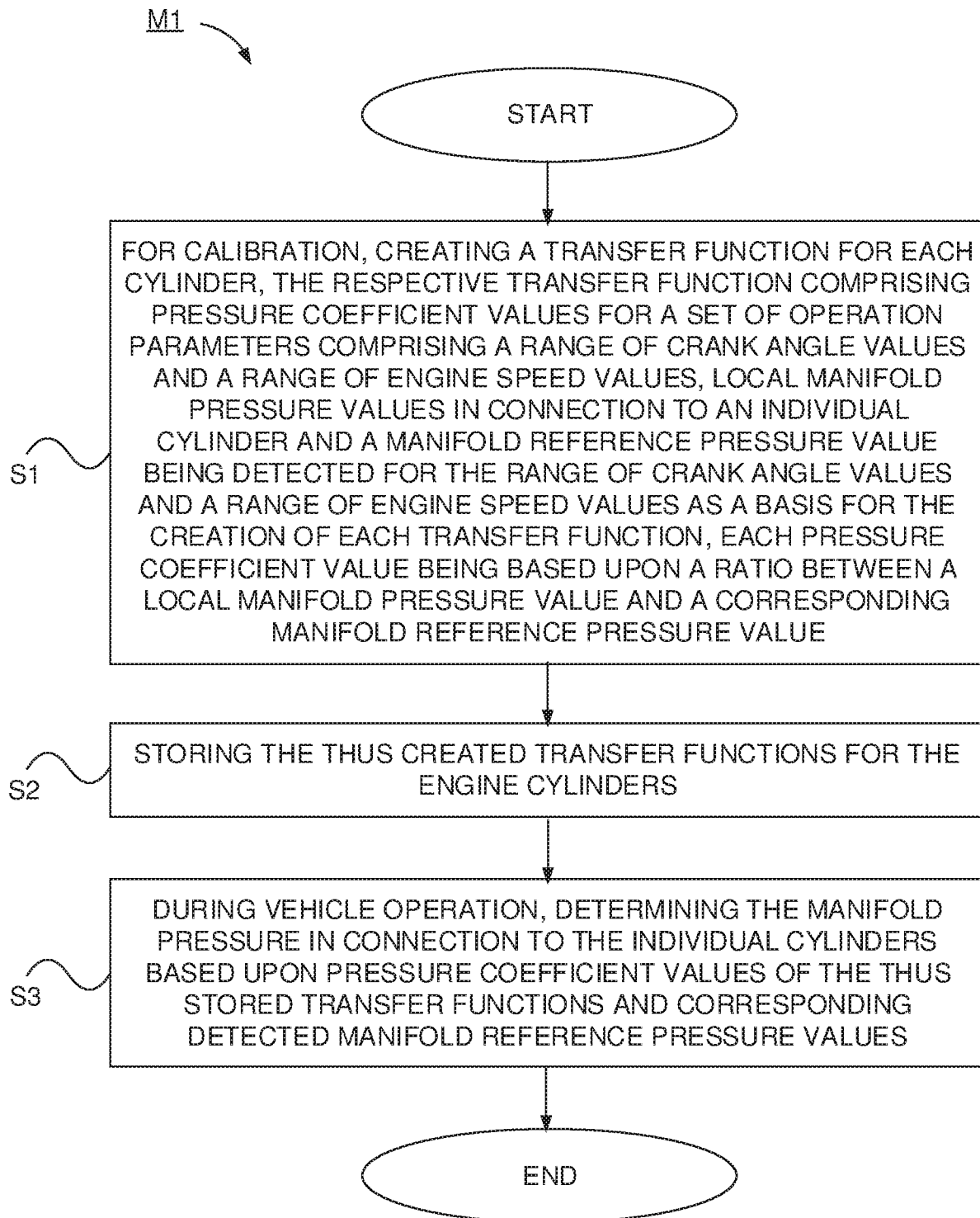


Fig. 6

5/6

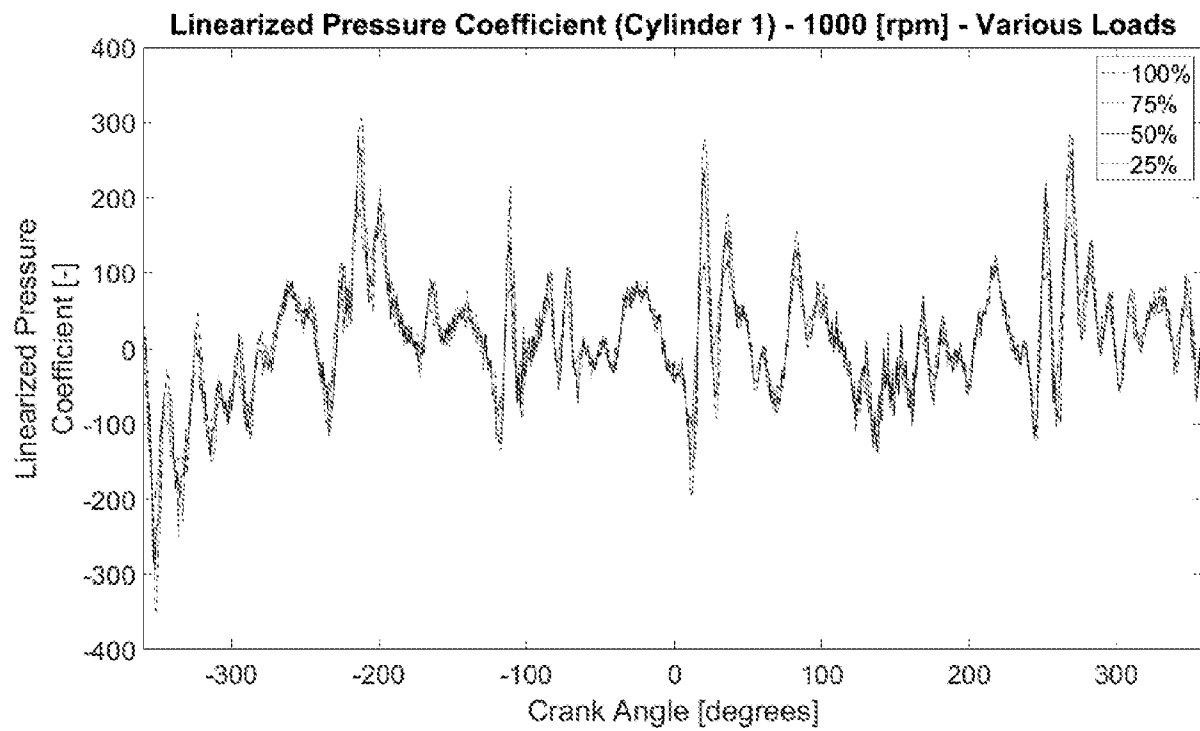


Fig. 7

T

Crank Angle [Degrees]	LPC 600 [rpm]	LPC 650 [rpm]	...	LPC 2350 [rpm]	LPC 2400 [rpm]
One Cycle	6.448	0.257	...	65.825	-12.995
	-5.082	7.567	...	50.981	-6.536
	...	...	...	...	...
	-27.453	7.990	...	56.394	16.698
	1.565	32.623	...	49.421	30.836

Fig. 8

6/6

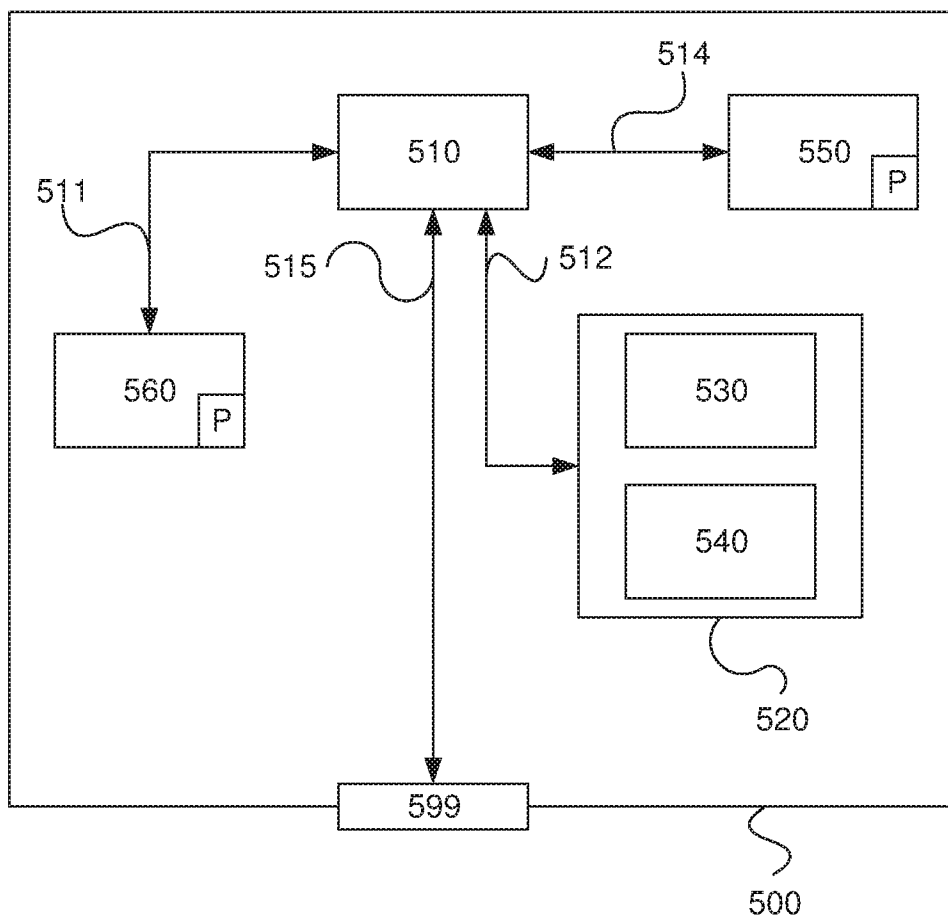


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2019/050563

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F01N, F02D, G01L

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20080091333 A1 (YAMASHITA HIROSHI ET AL), 17 April 2008 (2008-04-17); abstract; paragraphs [0006], [0031], [0061]-[0065] --	1-17
A	US 20160084171 A1 (OMURA TETSUO), 24 March 2016 (2016-03-24); paragraphs [0022]-[0023]; figure 1 --	1-17
A	US 20130268177 A1 (WU ZHIJIAN JAMES ET AL), 10 October 2013 (2013-10-10); abstract; paragraphs [0003], [0021], [0026]-[0027]; figures 1-2 --	1-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

20-08-2019

Date of mailing of the international search report

26-08-2019

Name and mailing address of the ISA/SE

Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer

Niels Rasmussen

Telephone No. + 46 8 782 28 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2019/050563

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20170101956 A1 (YOUNKINS MATTHEW A ET AL), 13 April 2017 (2017-04-13); paragraphs [0089]-[0091], [0096]; figure 15; claim 10 --	1-17
A	US 20170115181 A1 (BLOM ROGIER SEBASTIAAN ET AL), 27 April 2017 (2017-04-27); abstract; paragraphs [0084]-[0085]; figure 1 -- -----	1-17

Continuation of: second sheet

International Patent Classification (IPC)

F02D 41/14 (2006.01)

G01L 23/24 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2019/050563

US	20080091333 A1	17/04/2008	CN	101220779 B	03/11/2010
			DE	102007000821 B4	05/02/2015
			JP	2008095642 A	24/04/2008
			JP	4614104 B2	19/01/2011
			US	7630821 B2	08/12/2009
US	20160084171 A1	24/03/2016	CN	105164390 B	02/10/2018
			EP	2998544 B1	26/12/2018
			JP	2014224508 A	04/12/2014
			JP	5943310 B2	05/07/2016
			US	10094301 B2	09/10/2018
			WO	2014185493 A1	20/11/2014
US	20130268177 A1	10/10/2013	NONE		
US	20170101956 A1	13/04/2017	US	9890732 B2	13/02/2018
US	20170115181 A1	27/04/2017	EP	3368758 A1	05/09/2018
			US	10067033 B2	04/09/2018
			WO	2017074598 A1	04/05/2017