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(54) AIR INTAKE SYSTEM FOR A VEHICLE'S INTERNAL COMBUSTION ENGINE

(57) An air intake system for an internal combustion engine of a vehicle includes an inlet duct and a bypass duct. The bypass duct is led out from the inlet duct downstream a compressor and a charging air cooler and upstream the pressure sensor in a spark-ignition SI engine or upstream a throttle in a compressionignition CI engine and it is connected back to the intake duct upstream the compressor. In the bypass duct a circulation valve connected by wire or wireless connection to a digital computing and controlling system is provided. The system is characterized in that it uses an exhaust gas recirculation EGR valve with electromagnetic control unit as the circulation valve (5), wherein the digital computing and controlling system is the electronic control unit ECU of the vehicle.

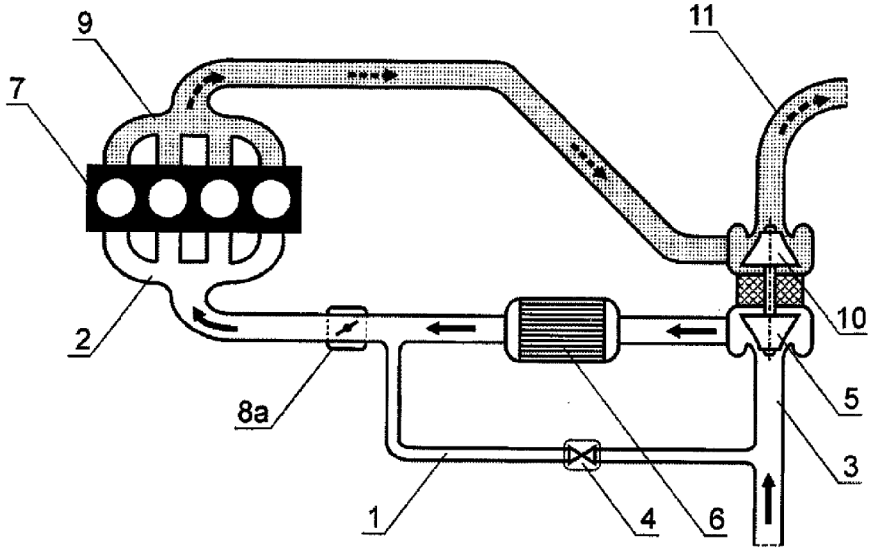

Fig. 1

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Description

[0001] The invention relates to is an air intake system for an internal combustion engine of a vehicle for use in the automotive industry, particularly in the construction of internal combustion supercharged engines supercharged by a turbo-supercharger and a mechanical compressor.

[0002] The use of a turbo-supercharger unit, which utilizes energy of exhaust gases to compress the inlet air in reciprocating internal combustion engines, both in spark-ignition SI engine and compression-ignition CI engine, makes it possible to obtain more power for a given engine displacement volume unit. Apart from benefits in a performance such a turbo-supercharging also brings technical problems due to the gas-dynamic relationship of exhaust gas output rate and the air demand, with the inertia of a rotating combined mass of a turbine, a shaft and a compressor rotor. The main problems are the phenomena popularly called by practitioners: "turbo lag" and "pumping". "Turbo lag" is the delay time between the action of increasing a load and a response of the engine, that is the delay between the instantaneous exhaust gas output rate and the air demand occurring at that moment. It results from the inertia of the mass of the rotating components of the turbo-supercharger and the volume of an air inlet ducts and an intermediate cooler that is built-in into the inlet duct between a turbine and an intake manifold. "Pumping" in a spark-ignition SI engine occurs when an air throttle is closed causing an increase in a pressure in the intake duct on the pressure side of a compressor, while downstream of the throttle both a drop of the mixture pressure and a drop of a temperature below the ignition temperature occur; the resulting lean mixture of fuel burns with detonations in the exhaust system. In a compression-ignition CI engine an increase in a pressure and in a temperature in a combustion chambers with simultaneous depletion of the mixture with a small dose of a fuel occurs. "Pumping" in a spark-ignition SI engine most often is eliminated by means of use of a bypass duct, which extends out from the intake duct downstream of a compressor and, if possible, downstream of an intermediate cooler, and which is connected back upstream the compressor. A circulation valve controlled by a two-position electromagnetic actuator by the signal of the air flow sensor in the intake duct is built into the bypass duct. Such a solution is presented, among others, in the European patent PL/EP1941138B1 specification, that is provided with a circulation valve having a pressure equalizing design on both sides of a shutoff element, with a preferred reduction of an the opening force of the electromagnet. In a compression-ignition CI engine, when the fuel dose is reduced, a bleed valve built into the intake duct downstream the compressor releases over-pressure to the atmosphere. In both cases, a valve action reduces a sudden loading of the compressor by a pressure surge on the pressure side, which allows the turbine to maintain a relatively high speed of rotation during open-valve operation and reduces an energy and time of increasing the compressor speed of rotation following the increasing the loading. In addition to the above-described solutions for improving operation of the turbocharger in a reciprocating internal combustion engine, solutions utilizing a digital technology to control a flow of exhaust gases and air through a turbocharger on the basis of a software analysis of engine operating parameters are also known. For example, mention can be made of the solutions presented in patents PL/EP1741895B1, PL/EP2488732B1, PL167486B1.

[0003] A method of controlling a speed of rotation of a turbocharger is disclosed in the Polish patent No. P.435784 which is supercharging of a reciprocating internal combustion engine, wherein this controlling is implemented in a system containing an intake duct and a bypass duct equipped with a circulation valve and led out from the intake duct downstream of a compressor and an intermediate cooler, and connected back to the inlet duct upstream the compressor. In a bypass duct a circulation valve controlled by an electric actuator according to an output signal from a digital computing system, the signal which is determined by a software for processing input signals of engine operating parameters, including those from built in the intake duct: an airflow sensor in a spark-ignition SI engine or a pressure sensor in a compression-ignition CI engine.

[0004] The present invention solves a technical problem that occurs in engines equipped with compressors, particularly with turbochargers (turbosuperchargers) consisting in that a delay occurs, so-called "turbo lag", between pressing an accelerator pedal and a response of the engine. This results from the inertia of a compressor/turbo-supercharger, a volume of an air intake ducts and a cooler between a turbine and an inlet to engine cylinders. For proper operation of the turbo-supercharger in order to generate a proper boost pressure, it is necessary to burn some additional fuel dose to obtain an exhaust gas for driving the turbo-supercharger.

[0005] The air intake system for an internal combustion engine of a vehicle includes an intake duct and a bypass duct, wherein the bypass duct is led out from the inlet duct downstream the compressor and charging air cooler and upstream the pressure sensor in a spark-ignition SI engine or upstream the throttle valve in a compression-ignition CI engine, and it is connected back to the intake duct upstream the compressor, wherein in the bypass duct a circulation valve connected by wire or wireless connection to a digital computing and controlling system is provided, and further wherein the essence of which the system consists in that the circulation valve is the exhaust gas recirculation EGR valve and the digital computing and controlling system is an electronic control unit ECU of a vehicle.

[0006] Preferably the computing and controlling system has a software and settings of threshold values of the circulation valve that are the same as for the operation mode of the exhaust gas recirculation EGR valve in-

stalled in the conduit originally connecting the exhaust duct to the intake duct.

[0007] In order to avoid engine malfunctions, preferably, the bypass duct is connected back to the intake duct between the compressor and the air flow sensor or the boost pressure sensor.

[0008] Advantageously by using the invention one can maintain the turbo-supercharger at a relatively high speed of rotation all the time in an idling range, low or medium load range of the engine with no need to be accelerated in any case when a demand for more power occurs i.e. greater boost pressure. This allows the engine to get the required power faster i.e. it reduces so-called "turbo lag." Additional advantage of using the exhaust gas recirculation EGR valve as an air circulation valve according to the invention is that the air circulating in a closed circuit (the compressor, the cooler, the bypass duct with EGR valve, the compressor) repeatedly passes through the cooler which allowing for deeper cooling of the air, and consequently lowering the temperature of the supercharging air, that results in increasing the engine power and efficiency.

[0009] The solution of the invention is presented in embodiment in the drawing, in which Fig. 1 shows in a simplified manner an air intake system for a spark-ignition SI internal combustion engine, and Fig. 2 - an air intake system for a compression-ignition CI internal combustion engine.

[0010] The air intake system for the spark-ignition SI internal combustion engine (Fig. 1) includes a bypass duct 1 connecting an intake manifold 2 to air intake duct 3. In the bypass duct 1, a circulation valve 4 with electromagnetic control unit is installed, which is a valve originally serving as an exhaust gas recirculation EGR valve in the known system. A compressor 5 in the air intake duct 3 at its air intake side is provided and followed by a charging air cooler 6 and a throttle 8a connected to the electronic control unit ECU of the vehicle. The bypass duct 1 is led out from the intake duct 3 downstream the compressor 5 and the charging air cooler 6 and upstream the throttle 8a, and it is connected back to the intake duct 3 between the compressor 5 and the air flow sensor, not shown in the drawing. The circulation valve 4 is connected by a signal wire to a digital computing and controlling system, not shown in the drawing, which is an electronic control unit ECU of the vehicle, equipped with a software and settings of the threshold values of the circulation valve 5, which are the same as those for the operating mode of the exhaust gas recirculation EGR valve that originally is installed on the conduit connecting the exhaust gas outlet duct 11 to the air intake duct 3. The exhaust gas outlet duct 11 is connected on one side to the exhaust gas outlet manifold 9 and is provided with a turbine 10, connected by means of a common shaft to the compressor 5.

[0011] In the second example of the air intake system for a compression-ignition CI internal combustion engine (Fig. 2) the difference is in that the bypass duct 1 is led out from the intake duct 3 downstream the compressor 5 and the charging air cooler 6 and upstream the pressure sensor 8b, and it is connected back to the inlet duct upstream the compressor 5.

[0012] The operation of the air intake system for an internal combustion engine of a vehicle consists in that the EGR valve, acting as a recirculation valve 4, partially takes over the function of controlling the boost pressure of the internal combustion engine 7. In a standard system with exhaust gas recirculation, the exhaust gas recirculation EGR valve opens at idle run and at low engine loads in order to apply a dose of exhaust gas to the cylinders which aims to reduce the amount of nitrogen oxides in the exhaust gas. In the present invention the EGR valve is also opened fully or partially at a partial load of the engine as well as at idle run, due to the same controlling by the electronic control unit ECU of the vehicle. When the EGR valve is open, the air flow is directed in the opposite direction to the direction of flow of an exhaust gas in a normally operating EGR valve. When the EGR valve is open (low load, idle run), a part of the air is returned back through the EGR valve upstream the compressor 5. The compressor 5 has lower resistance and therefore operates at a higher speed of rotation (revs), with greater flow, that is, with greater efficiency. The part of the air required by the engine 7 is taken from the air filter and is delivered to the cylinders, whereas the remaining part thereof circulates in the closed circuit of the circulation circuit: the compressor 5 - the cooler 6 - the circulation valve 4, and is cooled continuously all the time, and when the circulation valve 4 is closed due to its inertia and the inertia of the accelerated turbo-supercharger, the pressure in the intake duct 3 increases quickly, because there is no need to overcome the high inertia of the air column and to accelerate of the turbo-supercharger 5 because it already has a higher speed of rotation.

[0013] Due to the actuator element for controlling the air flow in the intake system - the circulation valve 4 is the EGR valve that is usually in the given drive unit, it does not require any modification except of closing only of the exhaust gas outlet duct 11 of the exhaust manifold 9 of the exhaust gas towards the EGR valve, wherein the exhaust gas input to the EGR valve should be connected to a pipe tee located in the air intake duct 3 between the air filter and the compressor 5. The EGR valve is controlled by a system for monitoring the operating state of the engine which system analyzes the following parameters: engine speed of rotation and its change, accelerator pedal and clutch pedal positions, boost pressure and air flow to the engine, wherein it is also possible to modify to some extent the closing and opening thresholds of the EGR valve operating as the circulation valve 4 of the boost air of the internal combustion engine 1. The connection of the bypass duct 1 on the other side of the EGR valve remains unchanged and is generally located as close as possible to the intake manifold 2. In such a manner a circulation circuit is created that bypasses component elements that can allow the ECU to calculate the

mass of the air fed to the engine, such as a flow meter or a boost pressure sensor, in order to prevent the engine operation from being affected.

Claims

1. Air intake system for an internal combustion engine of a vehicle, comprising an intake duct and a bypass duct, wherein the bypass duct is led out from the intake duct downstream a compressor and a boost air cooler and upstream a pressure sensor in a spark-ignition SI engine or upstream a throttle in a compression-ignition CI engine and connected back to the inlet duct upstream the compressor, and wherein in the bypass duct a circulation valve is provided and connected by wire or wireless connection to a digital computing and controlling system, **characterized in that** the circulation valve (4) is constituted by the exhaust gas recirculation EGR valve and the digital computing and controlling system is constituted by the electronic control unit ECU of the vehicle.

2. The system according to claim. 1, **characterized in that** the computing and controlling system is provided with software and settings of the threshold values of the circulation valve (4) that are the same as these for the mode of operation of the exhaust gas recirculation EGR valve installed in the conduit connecting the exhaust duct (11) to the intake duct (3).

3. The system according to claim. 1, **characterized in that** the bypass duct (1) is connected back to the intake duct (3) between the compressor (5) and an air flow sensor or a boost pressure sensor.

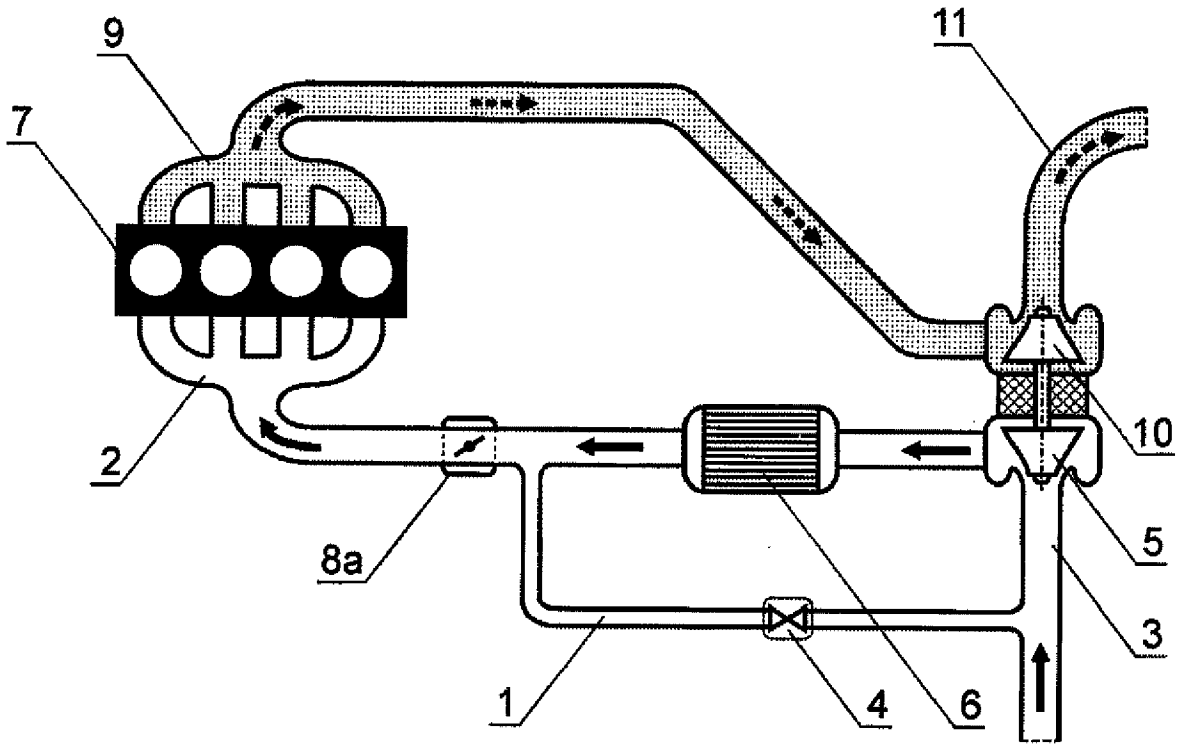

Fig. 1

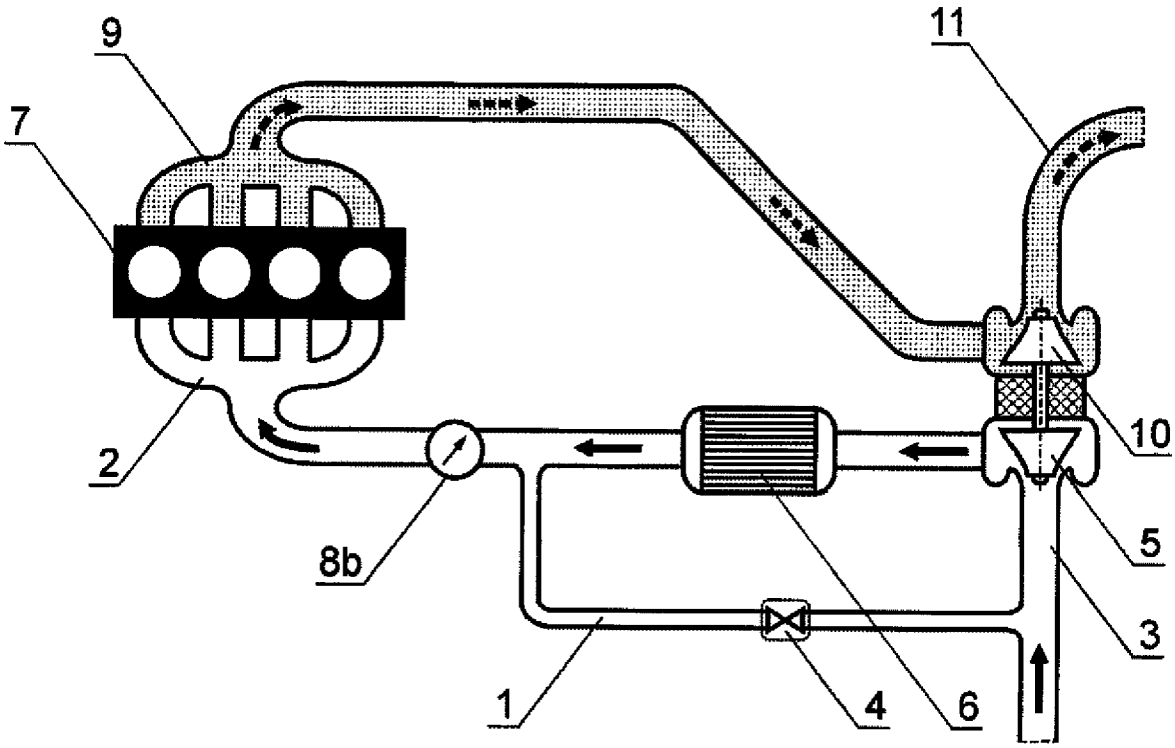

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 22 21 6713

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2011/155112 A1 (SCHIESTL STEFAN [AT] ET AL) 30 June 2011 (2011-06-30) * figure 1 *	1-3	INV. F02B29/04 F02B37/16
X	US 6 405 692 B1 (CHRISTIANSEN ERIK J [US]) 18 June 2002 (2002-06-18) * figures 2,3 *	1-3	
A	US 7 254 948 B2 (CUMMINS INC [US]) 14 August 2007 (2007-08-14) * figures 1,2 *	1-3	

TECHNICAL FIELDS SEARCHED (IPC)

F02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 May 2023	Kolodziejczyk, Piotr

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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