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(54) METHOD FOR STARTING A PRESSURE-CHARGED INTERNAL-COMBUSTION ENGINE AND APPARATUS FOR IMPLEMENTING THE METHOD

(71) We, BBC BROWN, BOVERI AND COMPANY LIMITED, a Swiss Company, of CH—5401, Baden, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a method for starting a pressure-charged internal-combustion engine which at the beginning of the starting phase receives the combustion air via a bypass valve and during this time a throttle valve in a charge-air line from a pressure-charging device to the engine is closed, the invention also concerning apparatus for implementing the method.

With pressure-charged internal-combustion engines, starting presents certain difficulties, as also does running at low partial loads. In the lower speed ranges an exhaust-gas turbocharger supplies too little combustion air, and so the engine has to aspirate the necessary air itself or else receives only an insufficient quantity, the result of which is poor combustion. When a gas-dynamic pressure wave machine is used as the pressure-charging device, excessive recirculation of exhaust gases occurs in the lowest speed ranges, i.e. too much exhaust gas passes into the combustion air, so that the engine can be started only with difficulty, if at all.

A remedy has been found by providing a throttle valve in the charge-air line from the pressure-charging device to the engine which is closed during starting, for example, and a bypass valve through which the engine, during starting, aspirates combustion air direct from the surroundings. The throttle valve can be operated automatically.

Thus a method is known (US Patent 2,853,987) in which, in an engine charged by a pressure-wave machine, the bypass valve and the throttle valve are actuated by the pressure difference between the compressed combustion air and the engine exhaust gases flowing to the pressure-wave machine. Such a concept of automatic control is not practicable because even at half-load and below, this pressure difference becomes negative over the whole speed range. The pressure-wave machine would then be inoperative and the engine would function merely as a naturally aspirating engine.

A further disadvantage when the throttle valve is actuated by the pressure difference, and also when it is actuated by the air pressure alone, by the pressure or temperature of the engine exhaust gases, or by the travel of the injection pump governor rod, etc., is that control of this kind results in irritating chattering of the throttle valve. In the case of a vehicle diesel engine, for example, the load, speed and exhaust temperature are continually varying, and hence also the control variables stated are changing constantly, which acts directly on the control device in that it is constantly opening and closing.

An engine pressure-charged by a pressure-wave machine is also known (Swiss Patent 399,077) which during starting receives combustion air from a branch line which remains closed in normal operation. A throttle valve in the charge-air line is closed by the starter motor current during starting, and opens again as soon as the starter is no longer in operation. A control system of this kind is also not satisfactory. At very low intake temperatures the valve should not begin to open for approximately 60 to 90 sec, i.e. after the gas temperature upstream of the pressure-wave machine has reached about 100°C. However, the starter cannot be operated for 60 sec, let alone 90 sec.

The invention seeks to mitigate at least some of the foregoing disadvantages experienced with the prior art.

According to a first aspect of the present invention, there is provided a method of starting a pressure-charged internal-combustion engine having a throttle valve in the line connecting the engine air intake to the pressure-charging device which throttle valve is closed prior to starting of the engine and a bypass valve arranged between the engine and the throttle valve to provide combustion air when the engine is isloated from the pressure-charging device by the throttle valve, which method comprises utilising an operating parameter which is dependent upon the running of the engine and does not drop below a first predetermined value when the engine is running to produce a force for opening or closing the throttle valve, and controlling the application of the said force to the throttle valve by means of a control parameter dependent upon the operation of the pressure-charging device such that the throttle valve opens only when the control parameter attains a second predetermined value, the throttle valve, once open, being maintained open regardless of the value of the control parameter.

According to a second aspect of the invention, there is provided apparatus for use in a pressure-charged internal-combustion engine having a throttle valve in a line connecting the engine air intake to the pressure-charging device and a bypass valve, the apparatus comprising an actuating device for opening and closing the throttle valve, means for producing power for the actuating device when an operating parameter which is dependent upon the running of the engine lies above a first predetermined value, means for controlling the application of the said power to the actuating device in response to a control parameter dependent upon the operation of the pressure-charging device such that the throttle valve opens when the control parameter attains a second predetermined value, and means for maintaining the throttle valve open regardless of the subsequent value of the control parameter.

The advantages of the method lies in the use of two parameters, the action of the one for opening or closing the throttle valve being triggered by the other. By separating the two functions in this way it is possible to set the effective threshold of each parameter individually, thus allowing a wider range of application and specific adaptation.

An operating sequence for the throttle valve made possible in this way can be matched finely and dependably to the particular characteristics of the engine in the starting phase.

The throttle valve (if it is closed in its rest position, which need not necessarily be so) can be held open while the engine is running by the same operating variable which causes it to open, and not close until this variable falls below the specified minimum value, which can be set so that values below the minimum occur only when the engine is stopped. The result of this is that the throttle valve remains open under all operating conditions and also when the engine is idling, and thus causes no disturbing noise.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a basic flow diagram, and

Figure 2 illustrates an example of the invention, partly schematic and partly as a section through a simplified construction.

Like parts in the two figures are designated by like reference numerals.

In Figure 1, an internal-combustion engine 1 is charged by a pressure-charging device 2 *via* a charge-air line 3. A throttle valve 4 and a bypass valve 5 are located in the charge-air line 3. From the engine 1 a control line 6 leads to a valve 7 which is provided in a supply line 8 for an actuating medium. The supply line 8 leads to a control element 9 which incorporates a switching device 10 that blocks or enables the flow of actuating medium, through a connecting line 11, to an actuating device 12, which is also a part of the control element 9 and serves to open and close the throttle valve 4.

A control line 13 leads from the pressure-charging device 2 to a controller 14, which acts on the switching device 10. The control lines 15, 13 can also lead to the controller 14 from the engine 1, instead of from the pressure-charging device.

This arrangement functions in the following manner. An engine-dependent operating parameter which attains a predetermined value only when the engine is running opens valve 7 *via* control line 6, whereupon actuating medium is free to flow *via* supply line 8 to the control element 9, but switching device 10 prevents it from passing through. Not until a control parameter indicative of the operation of the pressure-charging device 2 coming from the engine 1 or from the pressure-charging device 2, and acting on the controller 14 *via* control line 13, has attained a predetermined, adjustable value does the controller 14 change the state of the switching device 10, to allow the actuating medium to pass through. The previously closed throttle valve 4 is opened by the actuating device 12, and remains in this position. As will be explained below

with reference to Fig. 2, the switching device 10 can be held in the open position directly or indirectly the engine-dependent operating parameter.

The bypass valve 5, which is opened only by the airflow induced by the running engine, closes again automatically as soon as compressed air flows through the opened throttle valve to the engine.

The valve 7 is held open by an engine-dependent operating parameter which after the starting phase, i.e. during operation, does not fall below a specified minimum value. The latter is so chosen that values below the minimum occur only when the engine is stopped. In this case, valve 7 shuts off the flow. The valve 7 is preferably so designed that it then not only seals off the actuating medium, but at the same time connects lines 8 and 11, which are still under pressure, to a drain to release the pressure in them. Releasing the pressure causes the actuating device 12 to close the throttle valve 4, and the switching device 10 returns to its original state, blocking the flow of the actuating medium.

If the actuating medium is under a pressure which is itself dependent upon the running of the engine, the valve 7 would be superfluous. This would be the case, for example, if the engine lubricating oil is used as actuating medium.

Examples of liquid or gaseous actuating media are: engine lubricating oil, hydraulic oil, cooling water or water from a source other than the engine, air from a brake compressor, and operating air in the case of construction machines. Examples of engine-dependent operating parameters include: pressure of engine lubricating oil, operating hydraulics or cooling water, pressure of steering hydraulics or from the converter of an automatic transmission, brake-air pressure, operating-air pressure, current of battery, starter or generator.

The use of an actuating medium can alternatively be combined with an electrical device. It can be of advantage, for example, to make the actuating medium operate an electrical pressure switch which alters the setting of the throttle valve. Examples of actuating devices are then: a hydraulic or pneumatic cylinder, a linear-piston motor, a rotary piston, a pivotal piston, bellows, a diaphragm; a geared electric motor, a rotary or linear magnet, and a spindle mechanism driven by an electric motor.

Examples of control parameters which represent the state of operation of the pressure charging device are: the charge-air pressure, gas pressure upstream of the pressure charging device, the difference between latter two pressures, the engine exhaust-gas temperature, the speed of engine or pressure-charging device, centrifugal force due to speed, travel of the injection pump governor rod, and electrical signals representative of these parameters.

The control parameters can act, for example, on the following corresponding controllers: an electrical pressure, temperature or rotational-speed operated switch, solenoid, slide valve, rotary slide valve or relay.

One of the many possible configurations is shown in Fig. 2. The pressure charging device 2 is a gas dynamic pressure-wave machine which pressure-charges the engine 1 *via* the charge-air line 3. The pressure-wave machine receives the engine exhaust gases *via* line 16, and the air to be compressed *via* line 17, the exhaust gas, after giving up energy, leaving *via* line 18. The bypass valve 5 is located in the charge-air line 3 directly after the throttle valve 4, when viewed in the direction of flow.

The supply line 8 is connected to the engine lubricating oil serving as actuating medium thus obviating the need for valve 7 in Fig. 1. The line 8 is therefore connected directly to control line 6 for the engine 1 and leads to the housing 19 which contains the controller and a part of the control element. The controller incorporates essentially a positioning device 20, which is held by a resilient diaphragm 21 and extends into a bore 22 of the housing 19. The pressure in the charge-air line 3, serving as a control parameter indicative of the operation of the pressure wave machine, acts *via* control line 13 on the underside of the positioning device 20 and diaphragm 21. If the positioning device 20 is moved, it in turn moves the switching device, comprising a piston 23 located in bore 22, against the force of a spring 24. When the movement of piston 23 is sufficiently large, a duct 25 in the the piston establishes communication between supply line 8 and line 11 connecting to the actuating device. This is here in the form of pressure cylinder 26 on the piston 27 of which the engine lubricating oil acts directly as an engine-dependent operating variable. The piston 27 is in this way displaced againt the force of springs 28 (to the left in the drawing) and opens the throttle valve 4.

The controller, and in particular the diaphragm 21, is of such dimensions that it responds only when the pressure in the charge-air line 3 is higher than that obtained at the so-called slow idling speed. This is necessary because the throttle valve would otherwise open during the starting phase (by which is meant the time from the commencement of starting from cold up to and including slow idling). However, the valve must not open until the control parameter, in this case the charge-air

pressure, rises further, this being achieved by increasing engine speed, e.g. by accelerating at no-load, or by loading the engine.

In normal operation it repeatedly happens that engine speed is reduced to slow idling but as the engine is still running, the throttle valve 4 should remain open. In order that the piston 23 should not then retract and close the throttle valve 4 again, the piston is mechanically joined to a holding device 29, on one side of which the pressure in the connecting line 11 acts via duct 30, this pressure being counteracted on the other side by the force of spring 24. This ensures that an effective link is continuously maintained from the engine up to the actuating device for the throttle valve. It is to be understood that a port in the piston 23 or a connection outside the housing 19 can be provided instead of duct 30.

The actuating device is adjusted so that it holds the throttle valve open as long as the engine-dependent operating parameter that is to say in this case the engine oil pressure does not fall below a specified minimum value. This minimum is so chosen that lower values do not occur even when the engine is idling. In this way, annoying chattering of the throttle valve is prevented even with continually changing operating conditions as occur, for example, with a vehicle engine.

If the engine is stopped, the lubricating oil pressure falls below the specified minimum value. The spring 28 expels the lubricating oil present in the pressure cylinder 26, and in so doing closes the throttle valve 4. The pressure in the charge-air line 3 also falls, whereupon the pressure on the positioning device 20 decreases and the positioning device 20 is reset by the restoring force of the diaphragm 21 or by the spring 24, together with the piston 23.

If, as in the present example, the engine lubricating oil is the actuating medium, it can take a long time, especially in cold weather, before the lubricating oil has run back after stopping the engine. So that the piston 23 does not close the flow off again prematurely, leaving the throttle valve 4 partly open, the spring 24 can be made weak so that it comes into action only if the pressure falls very sharply on the other side of the holding device 29. Despite this, it could happen that through closing off the return flow of actuating medium too quickly, the throttle valve is not completely closed, or that the release of pressure in lines 8 and 11 occurs too slowly. In these cases a rapid vent valve 31 for draining the connecting line 11 can be of advantage.

It has hitherto been implicitly assumed that the throttle valve is closed in the rest position and during operation is held open in the manner described, or a similar manner. The present method, however, can equally be applied if the throttle valve is open in the rest position, and closed only in the starting phase. It can, for example, be closed simultaneously with connection of the starter current, and returned to its open rest position only when the control parameter representative of the start of operation of the pressure-charging device indicates actuation of the throttle valve by the engine-dependent operating parameter.

It can also be of benefit if the control facility is in the form of an electrical system through which the engine-dependent operating variable initiates actuation of the throttle valve.

WHAT WE CLAIM IS:—

1. A method of starting a pressure-charged internal-combustion engine having a throttle valve in the line connecting the engine air intake to the pressure-charging device which throttle valve is closed prior to starting of the engine and a bypass valve arraying between the engine and the throttle valve to provide combustion air when the engine is isolated from the pressure-charging device by the throttle valve, which method comprises utilising an operating parameter which is dependent upon the running of the engine and does not drop below a first predetermined value when the engine is running to produce a force for opening or closing the throttle valve, and controlling the application of the said force to the throttle valve by means of a control parameter dependent upon the operation of the pressure-charging device such that the throttle valve opens only when the control parameter attains a second predetermined value, the throttle valve, once open, being maintained open regardless of the value of the control parameter.

2. Apparatus for use in a pressure-charged internal-combustion engine having a throttle valve in a line connecting the engine air intake to the pressure-charging device and a bypass valve, the apparatus comprising an actuating device for opening and closing the throttle valve, means for producing power for the actuating device when an operating parameter which is dependent upon the running of the engine lies above a first predetermined value, means for controlling the application of the said power to the actuating device in response to a control parameter dependent upon the operation of the pressure-charging device such that the throttle valve opens when the control parameter attains a second predetermined value, and means for maintaining the throttle valve open regardless of the subsequent value of the control parameter.

3. Apparatus as claimed in Claim 2, in which the means for producing power for the actuating device comprise a source of pressurized fluid, the actuating device being fluid-operated.

4. Apparatus as claimed in Claim 3, wherein a fluid pressurized by the engine serves as actuating medium, the apparatus comprising a valve connected in a supply line for the actuating medium, the valve being operated in response to said operating parameter exceeding the said first predetermined value.

5. Apparatus as claimed in Claim 3 or Claim 4, in which the pressurised fluid acts on the electrical pressure switch in order to actuate the throttle valve.

6. Apparatus as claimed in Claim 2, in which the means for producing power for the actuating device comprises an electrical circuit, the actuating device being electrically operable.

7. Apparatus as claimed in any of Claims 2 to 6, in which the means for controlling the application of power to the actuating device comprise a switching device operative to adopt a displaced position in response to the said control parameter attaining the said second predetermined value to permit application of power to the actuating device.

8. Apparatus as claimed in Claim 7, in which the means for maintaining the throttle valve open regardless of the subsequent value of the control parameter comprise means for maintaining the switching device in its displaced position independently of the value of the said control parameter.

9. Apparatus as claimed in Claim 8, in which the switching device is mechanically connected to a holding device which is held in the displaced position as long as the said operating parameter lies above the said first predetermined value and returns together with the switching device to its original position under the action of an opposing force when the operating parameter drops below said first predetermined value.

10. Apparatus as claimed in Claim 9, when appended to any of claims 3 to 6, in which the holding device is acted upon by the pressurized fluid.

11. Apparatus as claimed in any of Claims 7 to 10 when appended to Claim 3, in which a rapid vent valve is provided in a line connecting the actuating device to the switching device.

12. Apparatus as claimed in any of Claims 7 to 11, in which the actuating device, is connected to close the throttle valve when the switching device returns to its original position.

13. A method of starting a pressure charged internal combustion engine having a throttle valve in the line connecting the engine air intake to the pressure charging device substantially as hereinbefore described, with reference to and as illustrated in the accompanying drawing.

14. Apparatus for starting a pressure charged internal combustion engine substantially as herein described, with reference to and as illustrated in the accompanying drawing.

MARKS & CLERK.

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1563147 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

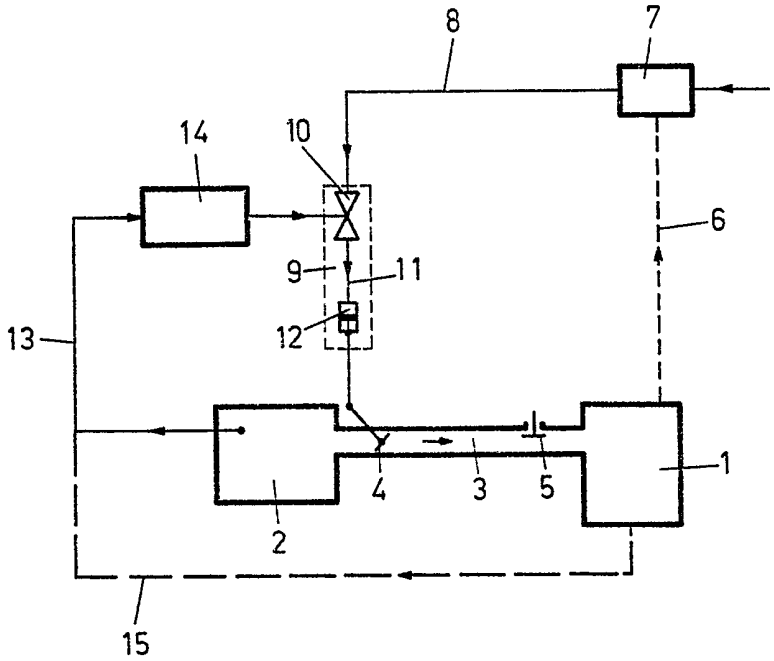

FIG.1

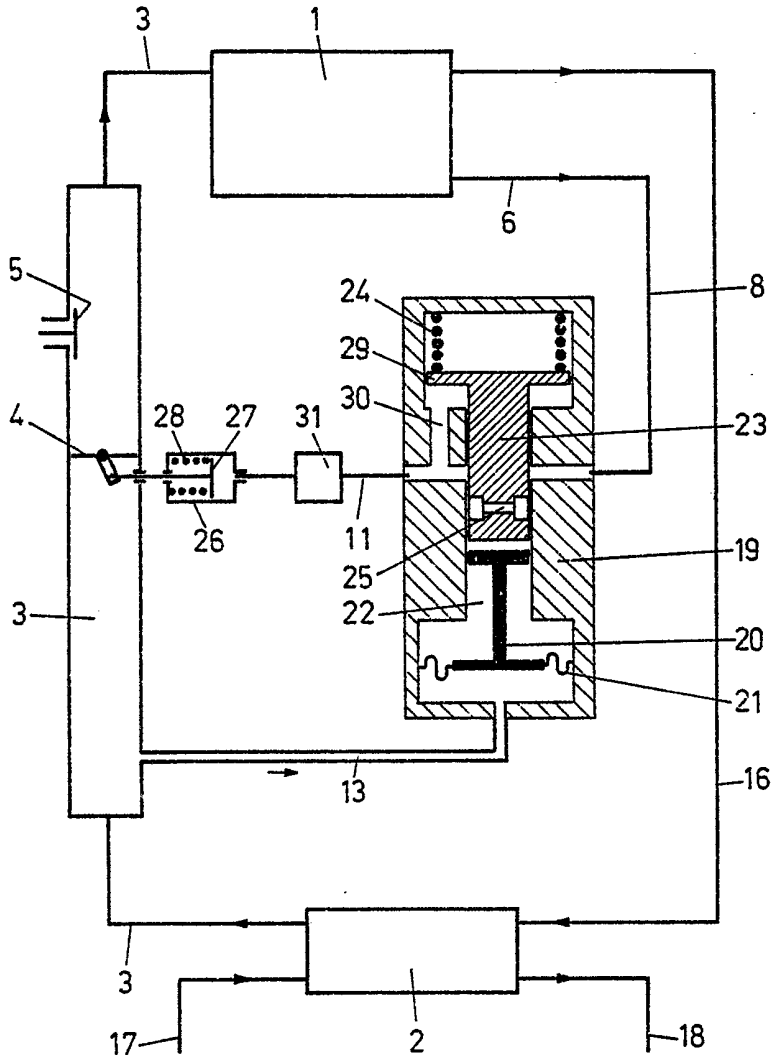

FIG. 2