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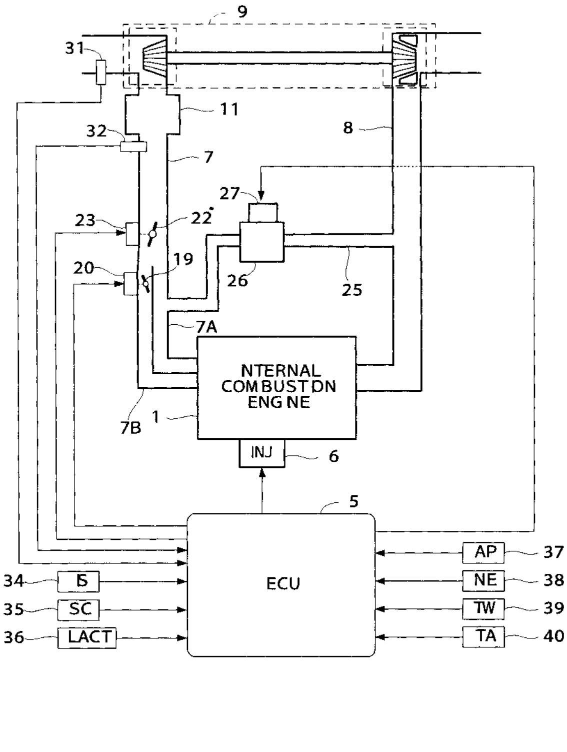
(54) **Control system for internal combustion engine**

(57) A control system for an internal combustion engine (1) having an air supply passage (7) for supplying air to the engine (1). The air supply passage (7) includes a first and a second branch passages respectively communicating with a combustion chamber of the engine (1). The engine (1) further includes an exhaust gas recirculation passage for recirculating a part of exhaust gases discharged from the combustion chamber to the first branch passage (7A), a first control valve (26) for controlling an amount of the recirculated exhaust gases, and a second control valve (22) disposed upstream of the first and the second branch passages for opening and closing the air supply passage (7). An operation speed of the second control valve (22) is reduced when closing the second control valve (22) during a valve opening operation of the first control valve (26). The recirculated exhaust gases are thereby prevented from flowing into the second passage where a swirl control valve is disposed, thereby avoiding sticking of the swirl control valve.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a control system for an internal combustion engine, and particularly to a control system for an internal combustion engine having a configuration wherein an intake passage branches out to two passages respectively communicating with a combustion chamber, and exhaust gases are recirculated to one of the two branch passages.

Description of the Related Art

[0002] As shown in FIG. 6, a configuration wherein an intake passage 102 of an internal combustion engine 101 branches out to branch passages 102A and 102B respectively communicating with a combustion chamber is shown in Japanese Patent Laid-open No. 2001-73881. In this configuration, a swirl control valve 104 is disposed in the branch passage 102B, an exhaust gas recirculation passage 105 is connected to the other branch passage 102A.

[0003] Further, a configuration in which an intake shutter valve 103 for controlling an intake air flow rate is disposed upstream of the branch passages 102A and 102B is also conventionally known.

[0004] When an exhaust gas recirculation valve 106 in the exhaust gas recirculation passage 105 is opened and the exhaust gas recirculation is being performed, the intake shutter valve 103 is normally opened. However, there is a case where the intake shutter valve 103 may be closed when performing the exhaust gas recirculation in a specific engine operating condition. In this case, the recirculated exhaust gases pass near the intake shutter valve 103 and flow around into the branch passage 102B from the branch passage 102A. Therefore, some components in the exhaust gases adhere to the swirl control valve 104, which may cause sticking of the valve.

SUMMARY OF THE INVENTION

[0005] The present invention is made in order to solve the above-described problem, and an object of the invention is to provide a control system for an internal combustion engine, which can prevent the recirculated exhaust gases from flowing into the branch passage where the swirl control valve is disposed, when the exhaust gas recirculation is being performed and a closing operation of the intake shutter valve becomes necessary.

[0006] In order to attain the above object, the present invention provides a control system for an internal combustion engine having an air supply passage (7) for supplying air to the engine. The air supply passage includes a first and a second branch passages (7A, 7B) respectively communicating with a combustion chamber of the engine. The engine further includes exhaust gas recirculation means (25) for recirculating a part of exhaust gases discharged from the combustion chamber to the first branch passage (7A), a first control valve (26) for controlling an amount of the exhaust gases recirculated by the exhaust gas recirculation means (25), and a second control valve (22) disposed upstream of the first and the second branch passages(7A, 7B) for opening and closing the air supply passage (7). The control system is characterized by including valve operation control means for reducing an operation speed of the second control valve (22) when closing the second control valve (22) during a valve opening operation of the first control valve (26).

[0007] With this configuration, when closing the second control valve during execution of the exhaust gas recirculation by opening the first control valve, the operation speed of the second control valve is controlled to decrease. Therefore, the recirculated exhaust gases are prevented from flowing around from the first branch passage to the second branch passage. Consequently, if the swirl control valve is, for example, disposed in the second branch passage, the problem that sticking of the swirl control valve may easily occur can be avoided.

[0008] Preferably, the valve operation control means reduces the operation speed of the second control valve (22) as an opening of the second control valve (22) decreases.

[0009] With this configuration, the operation speed of the second control valve is controlled so as to decrease as the opening of the second control valve decreases. The recirculated exhaust gases flow around into the second passage more easily as the opening of the second control valve decreases. Therefore, by reducing the operation speed of the second control valve as the opening decreases, the recirculated exhaust gases are surely prevented from flowing into the second passage when the opening of the second control valve is comparatively small. On the other hand, a rapid control of the second control valve can be performed when the opening of the second control valve is comparatively large and the recirculated exhaust gases hardly flow into the second branch passage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 shows a configuration of an internal combustion engine and a control system therefor according to one embodiment of the present invention;

[0011] FIG. 2 is a flowchart of a process for performing an opening control of the intake shutter valve;

[0012] FIG. 3 shows a table referred to in the process of FIG. 2;

[0013] FIG. 4 is a flowchart of a process for setting a flag referred to in the process of FIG. 2;

[0014] FIG. 5 is a time chart illustrating an operation example of the opening control of the intake shutter valve; and

[0015] FIG. 6 shows a known configuration of an engine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Preferred embodiments of the present invention will now be described with reference to the drawings.

[0017] FIG. 1 is a schematic diagram showing a configuration of an internal combustion engine and a control system therefor according to one embodiment of the present invention. An internal combustion engine 1 (hereinafter referred to as "engine") is a diesel engine in which fuel is injected directly into cylinders, wherein each cylinder is provided with a fuel injection valve 6. The fuel injection valve 6 is electrically connected to the electronic control unit 5 (hereinafter referred to as "ECU"). A valve opening time period and a valve opening timing of the fuel injection valve 6 are controlled by the ECU 5.

[0018] The engine 1 has an intake pipe 7, an exhaust pipe 8, and a turbocharger 9. The turbocharger 9 includes a turbine and a compressor connected to the turbine through a shaft. The turbine is rotationally driven by the kinetic energy of exhaust gases. The turbocharger 9 pressurizes (compresses) the intake air of the engine 1.

[0019] An intercooler 11 is provided downstream of the compressor in the intake pipe 7, and an intake shutter valve 22 (hereinafter referred to as "ISV") is disposed downstream of the intercooler 11. The ISV 22 is configured so as to be opened and closed by an ISV actuator 23. The ISV actuator 23 is connected to the ECU 5.

[0020] The intake pipe 7 branches out to intake pipes 7A and 7B downstream of the ISV 22, and further branches out corresponding to each cylinder. FIG. 1 shows a configuration corresponding to only one cylinder. Each cylinder of the engine 1 is provided with two intake valves (not shown) and two exhaust valves (not shown). Two intake ports (not shown), which are opened and closed by the two intake valves, are connected respectively to the intake pipes 7A and 7B.

[0021] Further, the intake pipe 7B is provided with a swirl control valve (hereinafter referred to as "SCV") which restricts an amount of air inhaled through the intake pipe 7B to generate a swirl in the combustion chamber of the engine 1. The SCV 19 is configured so as to be opened and closed by a SCV actuator 20. The actuator 20 is connected to ECU 5.

[0022] The SCV actuator 20 includes a motor which can rotate in normal and reverse directions. The SCV 19 is actuated in the opening direction by driving the motor in the normal direction, and actuated in the closing direction by driving the motor in the reverse direction.

[0023] An exhaust gas recirculation passage 25 for recirculating exhaust gases to the intake pipe 7A is provided between the exhaust pipe 8 and the intake pipe 7A. The exhaust gas recirculation passage 25 is provided with an exhaust gas recirculation control valve 26 (hereinafter referred to as "EGR valve") for controlling an amount of exhaust gases that are recirculated. The EGR valve 26 is configured to be opened and closed by an EGR actuator 27, and the EGR actuator 27 is connected to the ECU 5. The EGR actuator 27 includes a motor which can rotate in normal and reverse directions. The EGR valve 26 is actuated in the opening direction by driving the motor in the normal direction and actuated in the closing direction by driving the motor in the reverse direction.

[0024] The ECU 5 supplies a driving control signal of a variable duty ratio to the EGR actuator 27 and the SCV actuator 20, and performs opening controls of the SCV 19 and the EGR valve 26 through the EGR actuator 27 and the SCV actuator 20.

[0025] An intake air flow rate sensor 31 for detecting an intake air flow rate GA and a boost pressure sensor 32 for detecting a boost pressure PB are disposed in the intake pipe 7. Further, an ISV opening sensor 34 for detecting an opening IS of the ISV 22, a SCV opening sensor 35 for detecting an opening SC of the SCV 19, and an EGR valve opening sensor 36 for detecting an opening (lift amount) LACT of the EGR valve 26 are provided. The detection signals of these sensors 31 to 36 are supplied to the ECU 5.

[0026] An accelerator sensor 37 for detecting an operation amount AP (hereinafter referred to as "accelerator pedal operation amount") of an accelerator pedal of the vehicle driven by the engine 1, an engine rotational speed sensor 38 for detecting an engine rotational speed NE, a coolant temperature sensor 39 for detecting an engine coolant temperature TW, and an ambient temperature sensor 40 for detecting an ambient temperature TA are connected to the ECU 5. The detection signals of these sensors are supplied to the ECU 5.

[0027] The ECU 5 includes an input circuit having various functions including a function of shaping the waveforms of input signals from the various sensors, a function of correcting the voltage levels of the input signals to a predetermined level, and a function of converting analog signal values into digital signal values. The ECU 5 further includes a central processing unit (hereinafter referred to as "CPU"), a memory circuit, and an output circuit. The memory circuit preliminarily stores various operating programs to be executed by the CPU and the results of computation or the like by the CPU. The output circuit supplies drive signals to the various actuators.

[0028] FIG. 2 is a flowchart of a process for calculating an opening command value ISCMD of the ISV 22. This process is executed by the CPU in the ECU 5 at predetermined time intervals (e.g., 20 milliseconds).

[0029] In step S11, a basic ISV opening command value ISCMDB(%) is calculated according to the accelerator pedal operation amount AP and the engine rotational speed NE. In step S12, it is determined whether or not a speed reduction flag FVRED is equal to "1". The speed reduction flag FVRED is set to "1" by the process of FIG. 4 described below when the engine 1 is in a predetermined operating condition.

[0030] If the answer to step S12 is negative (NO), the process immediately proceeds to step S17. If FVRED is equal to "1" in step S12, a reduction control command value ISCMDR is calculated in order to perform a control for reducing the ISV opening (step S13). The reduction control command value ISCMDR is set so that the ISV opening is gradually reduced.

[0031] In step S14, a TC table shown in FIG. 3 is retrieved according to the reduction control command value ISCMDR, to calculate a filter time constant TC. The TC table is set so that the filter time constant TC increase as the reduction control command value ISCMDR decreases. Predetermined preset values TC1 and TC2 shown in FIG. 4 are set, for example, to 0.15 seconds and 0.01 seconds, respectively.

[0032] In step S15, a filtering, specifically, a first-order delay filtering of the reduction control command value ISCMDR is performed. The filter time constant TC is applied to the first-order delay filtering. By performing the filtering, the reduction speed of the reduction control command value ISCMDR is decreased. In step S16, the basic ISV opening command value ISCMDB is set to the reduction control command value ISCMDR, and the process proceeds to step S 17.

[0033] In step S17, the basic ISV opening command value ISCMDB is corrected according to the engine coolant temperature TW, to calculate the ISV opening command value ISCMD.

[0034] The calculated ISV opening command value ISCMD is supplied to the ISV actuator 23, and the ISV 22 is controlled so that the ISV opening IS coincides with the ISV opening command value ISCMD.

[0035] FIG. 4 is a flowchart of a process for setting a speed reduction flag FVRED which is referred to in step S12 of FIG. 2. This process is executed by the CPU in the ECU 5 in the same cycle as that of the process of FIG. 2.

[0036] In step S21, it is determined whether or not the engine operating condition is in a predetermined EGR region where the exhaust gas recirculation is performed. Specifically, it is determined whether or not the detected coolant temperature TW and the detected ambient temperature TA are in the predetermined EGR region. If the answer to step S21 is negative (NO), the EGR valve 26 is closed (step S22) to stop the exhaust gas recirculation. The process proceeds to step S26, in which the speed reduction flag FVRED is set to "0".

[0037] If the answer to step S21 is affirmative (YES), the EGR valve 26 is opened to perform the exhaust gas recirculation (step S23). In step S24, it is determined whether or not the coolant temperature TW is equal to or less than a predetermined water temperature TWL (e.g., 60 degrees centigrade). If the answer to step S24 is affirmative (YES), it is determined whether or not the fuel cut operation in which the fuel supply to the engine 1 is interrupted, is being performed. (step S25).

[0038] If the answer to step S24 or S25 is negative (NO), the process proceeds to the above-described step S26. On the other hand, if the answer to step S25 is affirmative (YES), i.e., if the coolant temperature TW is equal to or less than the predetermined water temperature TWL and the fuel cut operation is being performed, the speed reduction flag FVRED is set to "1" (step S27).

[0039] As described above, in this embodiment, when the fuel cut operation is being performed in the state where the coolant temperature TW is equal to or less than the predetermined water temperature TWL during execution of the exhaust gas recirculation, the control for reducing the opening of the ISV 22 is performed. In the reducing control, the filtering for decreasing the reducing speed of the ISV opening is performed. According to this control of the ISV opening, the recirculated exhaust gases are prevented from flowing around into the intake pipe 7B from the intake pipe 7A.

[0040] Further, the filter time constant TC is set to a greater value, i.e., the reduction speed of the ISV opening is set to a smaller value as the reduction control command value ISCMDR decreases. Therefore, the recirculated exhaust gases are surely prevented from flowing around into the intake pipe 7B when the ISV opening is comparatively small. On the other hand, a rapid control of the ISV opening can be performed when the ISV opening is comparatively large and the recirculated exhaust gases hardly flow into the intake pipe 7B.

[0041] FIG. 5 is a time chart for illustrating an example of the control operation of the ISV opening in this embodiment. The solid line shows changes in the ISV opening when the filtering is performed. The dashed line shows changes in the ISV opening when the filtering is not performed (only the solid line is shown in the portion of the dashed line overlapped with the solid line). As shown in FIG. 5, the reduction speed of the ISV opening is controlled so as to decrease as the reduction speed of the ISV opening decreases during the periods TR1 and TR2 in which the speed reduction flag FVRED is set to "1" and the filtering is performed.

[0042] In this embodiment, the intake pipe 7 corresponds to the air supply passage. The intake pipes 7A and 7B respectively correspond to the first and the second branch passages. The exhaust gas recirculation passage 25 and the EGR valve 26 respectively correspond to the exhaust gas recirculation means and the first control valve. The intake shutter valve 22 corresponds to the second control valve. Further, the ECU 5 constitutes the valve operation control means. Specifically, the process shown in FIGs. 2 and 4 correspond to the valve operation control means.

[0043] The present invention is not limited to the embodiment described above, and various modifications may be made. For example, the process for decreasing the reduction speed of the ISV opening is not limited to the first-order delay filtering but other methods of the low pass filtering can be applied.

[0044] The present invention can be applied to a control system for a watercraft propulsion engine such as an outboard engine having a vertically extending crankshaft.

[0045] The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims, rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are, therefore, to be embraced therein.

Claims

1. A control system for an internal combustion engine (1) having an air supply passage (7) for supplying air to said engine (1), said air supply passage (7) including a first and a second branch passages respectively communicating with a combustion chamber of said engine (1), exhaust gas recirculation means (25) for recirculating a part of exhaust gases discharged from the combustion chamber to the first branch passage (7A), a first control valve (26) for controlling an amount of the exhaust gases recirculated by said exhaust gas recirculation means (25), and a second control valve (22) disposed upstream of said first and the second branch passages for opening and closing said air supply passage (7),
said control system being **characterized by** including
valve operation control means for reducing an operation speed of said second control valve (22) when closing said second control valve (22) during a valve opening operation of said first control valve (26).

2. A control system according to claim 1, wherein said valve operation control means reduces the operation speed of said second control valve (22) as an opening of the second control valve (22) decreases.

3. A control system according to any of the preceding claims, wherein said second branch passage is provided with a swirl control valve for generating a swirl in said combustion chamber.

4. A control system according to any of the preceding claims, further comprising coolant temperature detecting means for detecting a coolant temperature of said engine (1),
wherein said valve operation control means closes said second control valve (22) when said first control valve (26) is opened; the detected coolant temperature is less than or equal to a predetermined temperature; and the fuel supply to said engine (1) is interrupted.

5. A control method for an internal combustion engine (1) having an air supply passage (7) for supplying air to said engine (1), said air supply passage (7) including a first and a second branch passages respectively communicating with a combustion chamber of said engine (1), an exhaust gas recirculation mechanism for recirculating a part of exhaust gases discharged from the combustion chamber to the first branch passage (7A), a first control valve (26) for controlling an amount of the exhaust gases recirculated by said exhaust gas recirculation mechanism, and a second control valve (22) disposed upstream of said first and the second branch passages for opening and closing said air supply passage (7),
said control method being **characterized by** including the step of reducing an operation speed of said second control valve (22) when closing said second control valve (22) during a valve opening operation of said first control valve (26).

6. A control method according to any of the preceding claims, wherein the operation speed of said second control valve (22) is reduced as an opening of the second control valve (22) decreases.

7. A control method according to any of the preceding claims, wherein said second branch passage is provided with a swirl control valve for generating a swirl in said combustion chamber.

8. A control method according to any of the preceding claims, further including the step of detecting a coolant temperature of said engine (1),
wherein said second control valve (22) is closed when said first control valve (26) is opened; the detected coolant temperature is less than or equal to a predetermined temperature; and the fuel supply to said engine (1) is interrupted.

FIG. 1

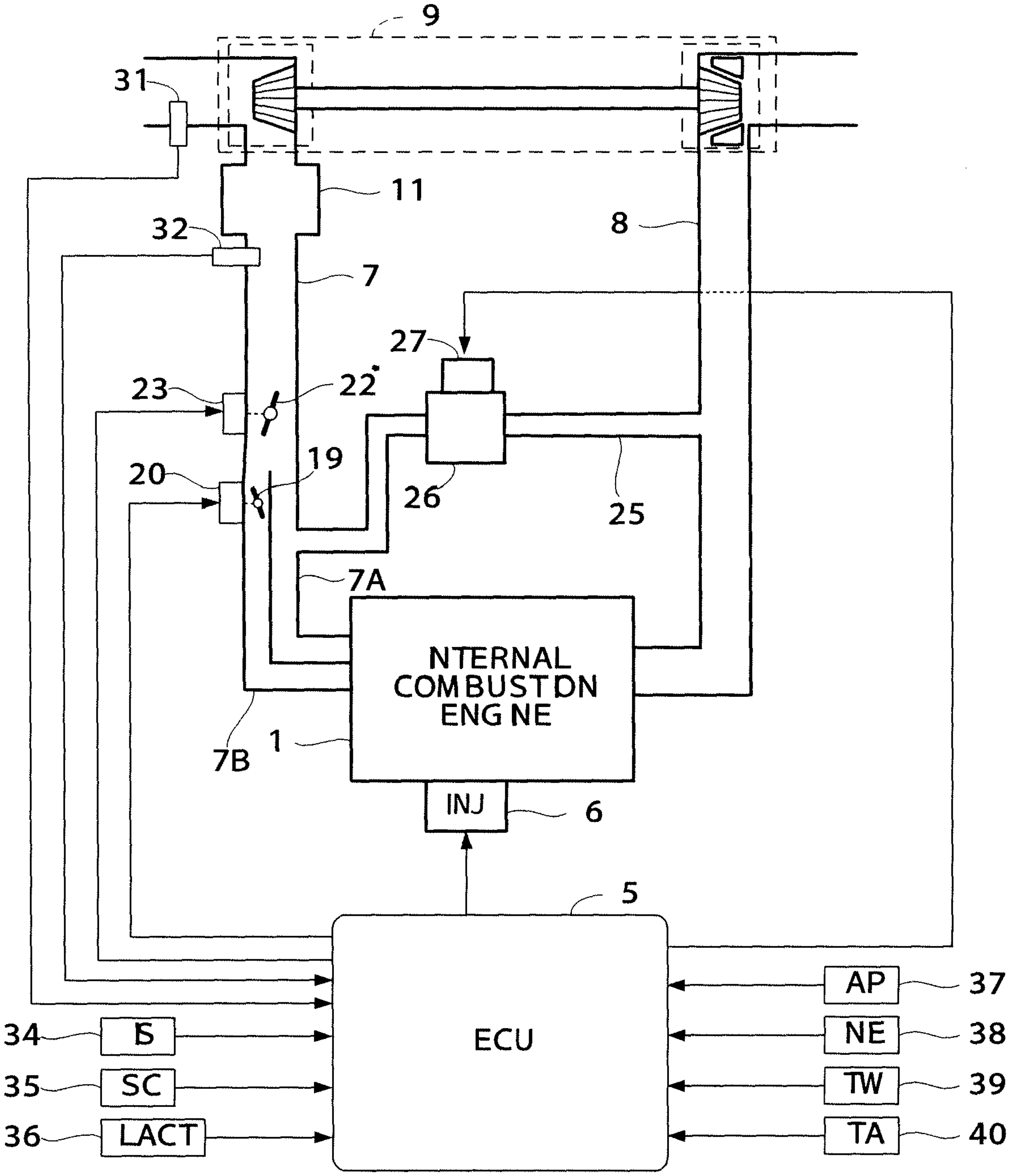

9
31
11
8
32
7
27
23
22
26
25
20
19
7A
NTERNAL COMBUSTDN ENG NE
7B
1
INJ
6
5
ECU
AP
37
NE
38
TW
39
TA
40
34
IS
35
SC
36
LACT

FIG. 2

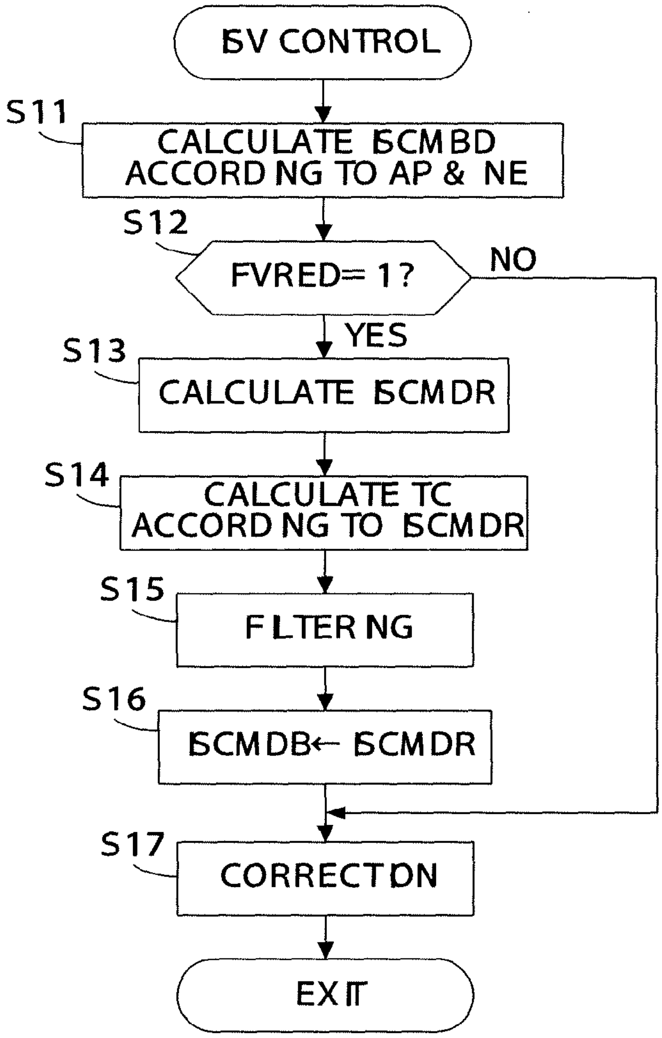

ISV CONTROL
S11
CALCULATE ISCMBD
ACCORDING TO AP & NE
S12
FVRED= 1?
NO
YES
S13
CALCULATE ISCMDR
S14
CALCULATE TC
ACCORDING TO ISCMDR
S15
FILTERING
S16
ISCMDB← ISCMDR
S17
CORRECTION
EXIT

FIG. 3

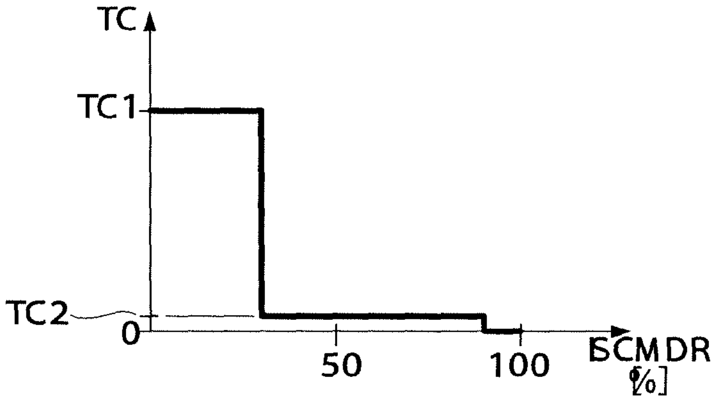

TC
TC1
TC2
0
50
100
ISCMDR
[%]

FIG. 4

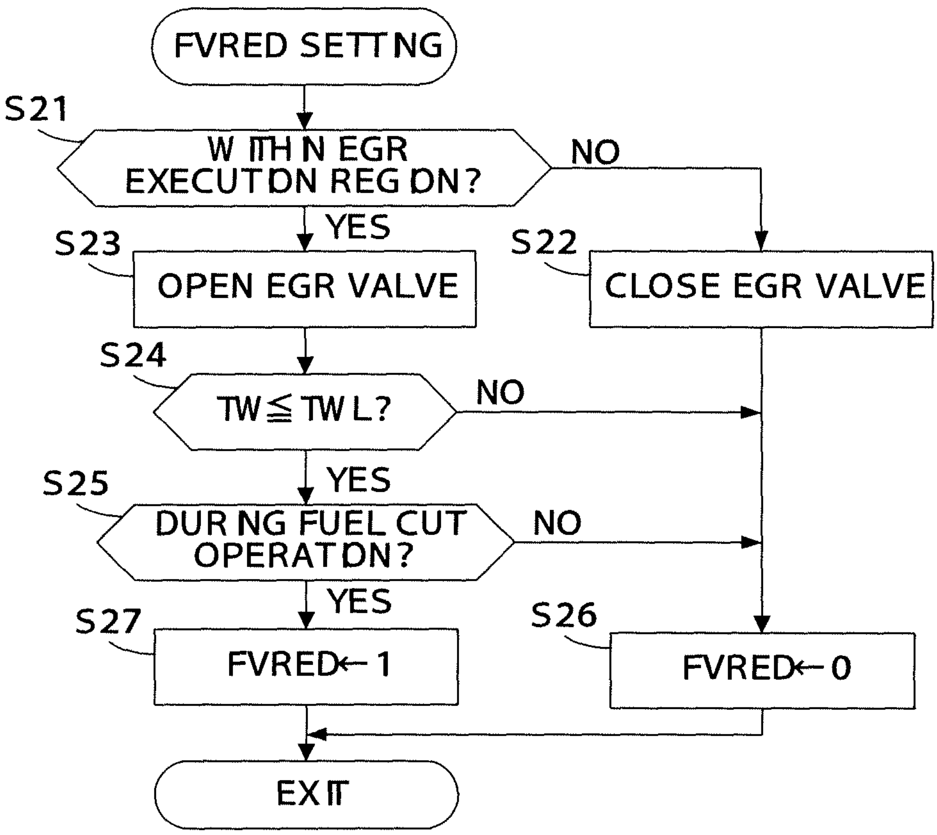

FVRED SETTING
S21
WITHIN EGR EXECUTION REGION?
NO
YES
S23
OPEN EGR VALVE
S22
CLOSE EGR VALVE
S24
TW≦TWL?
NO
YES
S25
DURING FUEL CUT OPERATION?
NO
YES
S27
FVRED←1
S26
FVRED←0
EXIT

FIG. 5

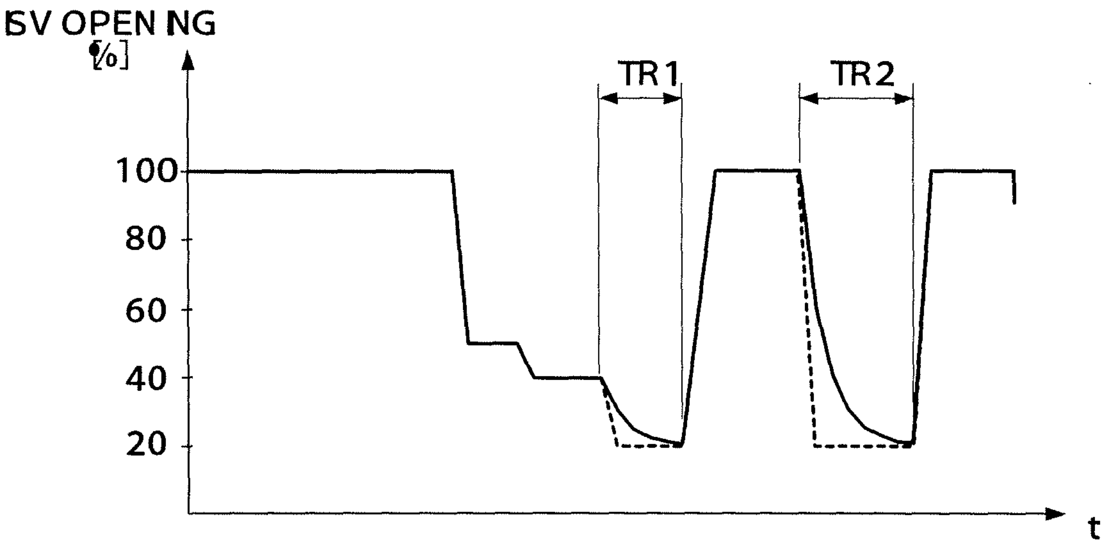
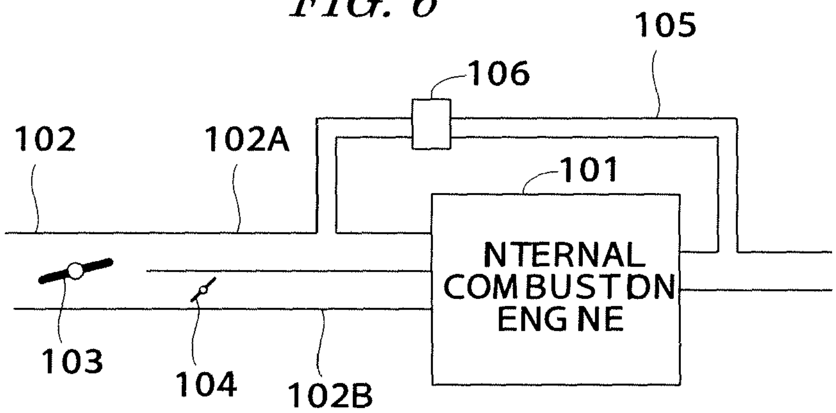

ISV OPENING [%]
TR1
TR2
100
80
60
40
20
t

FIG. 6



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EUROPEAN SEARCH REPORT

Application Number
EP 08 17 2980

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2003/196636 A1 (ASHIDA MASAAKI [JP] ET AL) 23 October 2003 (2003-10-23) * abstract * * figures 1,8,10 * -----		INV. F02D11/10 F02D41/10 F02M25/07
A	EP 1 617 056 A (HONDA MOTOR CO LTD [JP]) 18 January 2006 (2006-01-18) * abstract * * figure 1 * -----		
A	DE 43 10 839 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 6 October 1994 (1994-10-06) * the whole document * -----		
			TECHNICAL FIELDS SEARCHED (IPC)
			F02D F02M F02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	20 April 2009	Parmentier, Hélène

CATEGORY OF CITED DOCUMENTS

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4

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20-04-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP 2003314288 A	06-11-2003
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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