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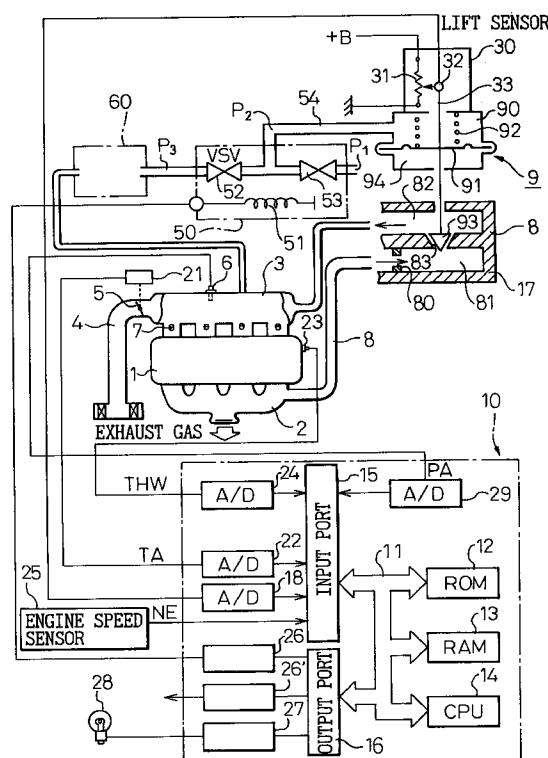
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(54) Exhaust gas recirculation system for internal combustion engine and method for detecting an abnormal condition thereof

(57) An exhaust gas recirculation (EGR) system for an internal combustion engine is capable of correctly determining whether or not an EGR control valve (9) is sound, irrespective of variations in the characteristics of a unit for setting a negative pressure applied to the EGR control valve or the aging of the unit.

The EGR system has the EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1), for controlling the flow rate of exhaust gas recirculated through the recirculation path (8), an aperture detector for detecting a real aperture of the EGR control valve (9) at proper intervals, a driver for driving the EGR control valve (9) in a way to provide a target aperture that is set at proper intervals according to operating conditions of the engine (1), and a diagnostic unit that determines that the EGR system including the EGR control valve (9) is abnormal if real apertures detected by the aperture detector do not follow corresponding target apertures after the target apertures show a change of predetermined magnitude.

Fig.1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an exhaust gas recirculation system for an internal combustion engine and a method of detecting an abnormal condition of the system. In particular, the present invention relates to an exhaust gas recirculation system for an internal combustion engine, provided with a unit for detecting an abnormality in the system and a method of detecting such an abnormality.

2. Description of the Related Art

An exhaust gas recirculation (EGR) system of an internal combustion engine recirculates exhaust gas from an exhaust path to an intake path through a recirculation path, to reduce NO_x in the exhaust gas. The EGR system has an EGR control valve in the recirculation path. The aperture of the EGR control valve is variable to control the flow rate of exhaust gas recirculated into the intake path. If the EGR control valve malfunctions, the recirculated exhaust gas will be excessive, too little, or stopped. If the recirculated exhaust gas is continuously excessive, a combustion speed in the engine slows down to deteriorate the output of the engine, and a combustion temperature in the engine drops to increase the amount of unburned components such as HC and CO. If the recirculated exhaust gas is continuously too little or stopped, the combustion speed and combustion temperature of the engine will be improper and emit a large amount of NO_x. What is worse is that the driver has no way to know of the excess, shortage, or stoppage of recirculated exhaust gas.

Various EGR systems for detecting a fault in an EGR control valve have been proposed. One of them is disclosed in Japanese Unexamined Patent Publication No. 6-299912. This system employs an EGR control valve whose aperture is controlled in response to a negative pressure, an aperture detector for detecting a real aperture of the EGR control valve, and a negative pressure setter for setting a negative pressure applied to the EGR control valve in a way to achieve a target aperture that is determined according to the operating conditions of an engine. The negative pressure applied to the EGR control valve is changed based on the real aperture thereof detected by the aperture detector, to optimize recirculated exhaust gas. More precisely, the negative pressure setter sets a negative pressure so that the EGR control valve may achieve a target aperture. After a predetermined time, the real aperture of the EGR control valve is detected by the aperture detector and is compared with the target aperture. If the difference between them is greater than a reference value, it is determined that the EGR control valve is faulty.

This disclosure, however, has a problem that the characteristics of the negative pressure setter fluctuate depending on atmospheric temperatures and the aging of parts such as springs thereof. Accordingly, a negative pressure supplied from the negative pressure setter to the EGR control valve may fluctuate around a value that corresponds to a target aperture determined based on the operating conditions of the engine. This results in fluctuating the real aperture of the EGR control valve detected by the aperture detector. Consequently, the real aperture fluctuates around the target aperture, and therefore, it is difficult to correctly determine whether or not the EGR control valve is sound.

SUMMARY OF THE INVENTION

An object of the present invention is to solve the problem mentioned above and provide an EGR system, for an internal combustion engine, capable of correctly determining whether or not an EGR control valve is sound, irrespective of variations in the characteristics of a unit for setting a negative pressure for the EGR control valve or the aging of the negative pressure setting unit.

In order to accomplish the object, the present invention provides an EGR system for an internal combustion engine, to diagnose an EGR control valve according to the responsivity of the EGR control valve with respect to target apertures, instead of comparing a real aperture with a specific target aperture.

A first aspect of the present invention provides an EGR system for an internal combustion engine, having an EGR control valve, disposed in a recirculation path that connects an exhaust path to an intake path of the engine, for controlling the flow rate of exhaust gas recirculated through the recirculation path, an aperture detector for detecting the real aperture of the EGR control valve at proper intervals, and a driver for driving the EGR control valve in a way to provide a target aperture that is set at proper intervals according to operating conditions of the engine. The system is characterized by a diagnostic unit. The diagnostic unit determines that the EGR system including the EGR control valve is abnormal if the real aperture detected by the aperture detector does not follow corresponding target aperture after the target apertures set according to the operating conditions of the engine show a change of predetermined magnitude. For example, if the difference between real and target apertures is greater than a reference value after a given period, the diagnostic unit determines that the EGR system including the EGR control valve is abnormal.

According to a second aspect of the present invention, the diagnostic unit determines that the EGR system including the EGR control valve is abnormal if a first period t_2 , which starts at the start of the change of predetermined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with a corresponding target aperture, is

greater than a first reference value t3.

According to a third aspect of the present invention, the diagnostic unit determines that the EGR system including the EGR control valve is abnormal if a second period t5, which starts at the start of the change of pre-determined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with a second target aperture that is set a given period t4 after the start of the change of predetermined magnitude in target apertures, is greater than a second reference value t6.

According to a fourth aspect of the present invention, the diagnostic unit maximizes, if a real aperture of the EGR control valve is smaller than a corresponding target aperture after a period t7 starting from t0 and if the difference between them is greater than a reference difference $\Delta L4$, the target aperture of the EGR control valve for a first continuation period "t8 - t7" until the difference between real and target apertures agrees with the reference difference $\Delta L4$ at t8 counted from t0, and determines that the EGR system including the EGR control valve is abnormal if the first continuation period "t8 - t7" is greater than a third reference value t9.

According to a fifth aspect of the present invention, the diagnostic unit minimizes, if a real aperture of the EGR control valve is greater than a corresponding target aperture after a period t10 starting from t0 and if the difference between them is greater than a reference difference $\Delta L5$, the target aperture of the EGR control valve for a second continuation period "t11 - t10" until the difference between real and target apertures agrees with the reference difference $\Delta L5$ at t11 counted from t0, and determines that the EGR system including the EGR control valve is abnormal if the second continuation period "t11 - t10" is greater than a fourth reference value t12.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood from the description as set forth below with reference to the accompanying drawings, wherein:

Fig. 1 shows an EGR system for an internal combustion engine according to an embodiment of the present invention;

Fig. 2 shows the details of a vacuum control valve shown in Fig. 1;

Fig. 3A is a flowchart showing a first routine of diagnosing an EGR control valve according to the present invention;

Fig. 3B is a flowchart showing a second routine of diagnosing the EGR control valve according to the present invention;

Fig. 4 is a graph showing lift in the EGR control valve based on the first and second routines;

Fig. 5 is a flowchart showing a third routine of diagnosing the EGR control valve according to the

present invention;

Fig. 6 is a graph showing lift in the EGR control valve based on the third routine;

Fig. 7 is a flowchart showing a fourth routine of diagnosing the EGR control valve according to the present invention;

Fig. 8 is a graph showing lift in the EGR control valve based on the fourth routine;

Fig. 9 is a flowchart showing a fifth routine of diagnosing the EGR control valve according to the present invention; and

Fig. 10 is a graph showing lift in the EGR control valve based on the fifth routine.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be described below with reference to the accompanying drawings.

Figure 1 shows an exhaust gas recirculation (EGR) system of an internal combustion engine according to the present invention. The EGR system has a diagnostic unit for determining whether or not the EGR system is sound. The engine 1 has an exhaust manifold 2, an intake manifold 3, and an intake duct 4. A throttle valve 5 is disposed in the intake duct 4. A pressure sensor 6 measures a pressure in the intake duct 4. A fuel injection valve 7 is arranged for each branch of the intake manifold 3. A recirculation path 8 connects the exhaust manifold 2 to the intake manifold 3. An EGR control valve 9 is arranged in the recirculation path 8. An electronic control unit (ECU) 10 controls these parts. When the EGR control valve 9 is open, exhaust gas in the exhaust manifold 2 is recirculated into the intake manifold 3 through the recirculation path 8.

The ECU 10 is, for example, a microcomputer. A two-way bus 11 connects parts of the ECU 10 to one another. The parts include a read-only memory (ROM) 12, a random access memory (RAM) 13, a central processing unit (CPU) 14, an input port 15, and an output port 16. The EGR control valve 9 is provided with a lift sensor 30 for detecting a lift, i.e., an aperture of a valve element. The output of the lift sensor 30 is supplied to the input port 15 through an A/D converter 18. The throttle valve 5 is connected to a throttle aperture sensor 21 for detecting the aperture of the throttle valve 5. The output TA of the sensor 21 is supplied to the input port 15 through an A/D converter 22.

The pressure sensor 6 is attached to a surge tank of the intake manifold 3 downstream from the throttle valve 5. The output PA of the pressure sensor 6 is supplied to the input port 15 through an A/D converter 29. The engine 1 has a water temperature sensor 23 for detecting the temperature of water for cooling the engine 1. The output THW of the sensor 23 is supplied to the input port 15 through an A/D converter 24. An engine speed sensor 25 generates a signal represent-

ing an engine revolution speed NE, which is supplied to the input port 15. An output port 16 is connected to drive circuits 26 and 26' for driving a vacuum switching valve 50 and the fuel injection valves 7, as well as to a drive circuit 27 connected to an alarm lamp 28.

According to this embodiment, the vacuum switching valve 50 is a solenoid valve composed of an electromagnetic coil 51, open-close valves 52 and 53, and a negative pressure guiding pipe 54. The pipe 54 has a branch P1 connected to the atmosphere through the valve 53, a branch P2 connected to the EGR control valve 9, and a branch P3 connected to a negative pressure generating unit through a vacuum control valve 60. The coil 51 receives an ON/OFF signal (a duty signal) from the drive circuit 26, to open and close the valves 52 and 53 so that a controlled negative pressure is supplied to a negative pressure chamber 90 of the EGR control valve 9 through the branch P2. The negative pressure generating unit to which the vacuum control valve 60 is connected is, for example, the intake manifold 3. The vacuum control valve 60 receives atmospheric pressure through a filter as well as a negative pressure from the intake manifold 3 and provides a controlled negative pressure of, for example, -130 mm Hg to the branch P3 without regard to the level of the negative pressure from the intake manifold 3.

The EGR control valve 9 has a diaphragm 91 that separates the inside of the valve 9 into the negative pressure chamber 90 and an atmospheric pressure chamber 94. The diaphragm 91 is fixed to a shaft 33. The chamber 90 incorporates a spring 92 to push the shaft 33 toward the chamber 94. The lift sensor 30 is attached to the EGR control valve 9 and consists of a variable resistor 31 and a brush 32. The brush 32 is fixed to the shaft 33 and slides together with the same. When the shaft 33 moves vertically in response to the negative pressure control valve 50, the position of the brush 32 on the variable resistor 31 changes to change a voltage supplied to the input port 15 through the A/D converter 18.

The valve element 93 is attached to a free end of the shaft 33, to close a valve seat 83 that is arranged in the middle of the recirculation path 8. A metering orifice 80 is arranged in the recirculation path 8 on the exhaust manifold 2 side of the valve seat 83. A section of the recirculation path 8 between the metering orifice 80 and the valve seat 83 defines a negative pressure chamber 81. A section of the recirculation path 8 between the valve seat 83 and the intake manifold 3 defines a recirculation path 82 on the intake side.

The ECU 10 detects a lift of the shaft 33 through the lift sensor 30 and feedback-controls the negative pressure control valve 50 to achieve a target lift that is determined according to the operating conditions of the engine. Here, real and target lifts of the shaft 33 correspond to real and target apertures of the EGR control valve 9. The ON/OFF signal (duty signal) is supplied to the coil 51, and the controlled negative pressure is sup-

plied to the EGR control valve 9 through the branch P2. The negative pressure opens the valve element 93 to guide exhaust gas from the exhaust manifold 2 into the intake manifold 3 through the recirculation path 8.

Figure 2 shows the details of the vacuum control valve 60. The valve 60 has an air filter 61 and is connected to the intake manifold 3 serving as the negative pressure generating unit. With the use of an atmospheric pressure receiving through the air filter 61 as well as a negative pressure receiving from the intake manifold 3, the valve 60 provides the branch P3 with the controlled pressure of, for example, -130 mm Hg irrespective of the level of the negative pressure from the intake manifold 3. The valve 60 has two states. In the first state, the negative pressure of the intake manifold 3 is applied to a first port 62. Then, a plate 63, retainer 64, and valve poppet 65 rise. Due to the controlled negative pressure, a pipe 66 stops the valve poppet 65, which tightly attaches to the lower end of the pipe 66, to seal the negative pressure. In practice, the plate 63, retainer 64, and valve poppet 65 have weight, and therefore, rise slowly. As a result, the lower end of the pipe 66 is sealed by the valve poppet 65 under a negative pressure that is stronger than the controlled negative pressure. Then, the plate 63 and retainer 64 further rise to set up the second state. In the second state, atmospheric air passing through the air filter 61 flows through an orifice 67 formed at the lower end of the retainer 64 and through a gap between the retainer 64 and the valve poppet 65. The air then flows into a diaphragm chamber 69 surrounded by diaphragms 68a and 68b. As a result, a spring 70 pushes down the plate 63, retainer 64, and valve poppet 65. Thereafter, the first and second states alternate to guide the controlled negative pressure from a second port 71 into the branch P3 of the solenoid valve 50.

Routines of the present invention of diagnosing whether or not the EGR control valve 9 is sound will be explained in detail. Any one of the routines is carried out by the ECU 10 when EGR conditions are met. Namely, any one of the routines takes place when the temperature THW of engine cooling water is above a given value, an engine operating state detected from the throttle aperture TA is steady and not transient, and a load on the engine detected according to the engine speed NE and load PA is medium. In the following explanation, real and target "lifts" are of the shaft 33 of the lift sensor 30 and are synonymous with real and target "apertures" of the EGR control valve 9.

Figure 3A is a flowchart showing a first routine of diagnosing the EGR control valve 9, Fig. 3B is a flowchart showing a second routine of diagnosing the same, and Fig. 4 is a graph showing lift in the EGR control valve 9 based on the first and second routines. In Fig. 4, an abscissa represents time, an ordinate represents lift, a continuous curve represents target lift, and a dotted curve represents real lift. The target lift start to change at t0. The first routine will be explained with reference to

Figs. 3A and 4.

Step 101 determines whether or not target lift LTG shows a change greater than a reference value $\Delta L1$ in a period $t1$ starting from $t0$ at which the target lift starts to change, where each target lift LTG is calculated from a map stored in the ROM 12 according to an engine speed NE and a load PA. If there is a change greater than $\Delta L1$, step 102 is carried out, and if not, the routine ends. Step 102 determines whether or not the difference $|LTG - LR|$ between a real lift LR detected by the lift sensor 30 a period $t2$ after $t0$ and a corresponding target lift LTG is greater than $\Delta L1$. For example, step 102 compares $|LTG - LR|$ with $k \cdot \Delta L1$ (k being 0.9) or with $\Delta L2$, and if $|LTG - LR| > k \cdot \Delta L1$, or

$|LTG - LR| > \Delta L2$, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 105 is carried out. If $|LTG - LR| \leq k \cdot \Delta L1$, or $|LTG - LR| \leq \Delta L2$, this routine ends. Step 105 turns on the alarm lamp 28 and terminates the routine.

The second routine will be explained with reference to Figs. 3B and 4.

Step 101 determines whether or not target lift LTG shows a change greater than a reference value $\Delta L1$ in a period $t1$ starting from $t0$ at which the target lift starts to change, where each target lift LTG is calculated from the map stored in the ROM 12 according to an engine speed NE and a load PA. If there is a change greater than $\Delta L1$, step 102 is carried out, and if not, the routine ends. Step 102 determines whether or not the difference $|LTG - LR|$ between a real lift LR detected by the lift sensor 30 and a corresponding target lift LTG is equal to or smaller than a reference value $\Delta L2$. If step 102 indicates YES, step 103 is carried out, and if not, the routine ends. Step 103 reads a period $t2$ that starts at $t0$ and ends at the time when the difference $|LTG - LR|$ becomes equal to or smaller than $\Delta L2$. Step 104 compares the period $t2$ with a reference value $t3$. If $t2 > t3$, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 105 is carried out. If $t2 \leq t3$, the valve 9 and sensor 30 are sound, and the routine ends. Step 105 turns on the alarm lamp 28, and the routine ends.

Figure 5 is a flowchart showing a third routine of diagnosing the EGR control valve 9, and Fig. 6 is a graph showing lift in the EGR control valve 9 based on the third routine. In Fig. 6, an abscissa represents time, an ordinate represents lift, a continuous curve represents target lift, and a dotted curve represents real lift.

Step 201 determines whether or not target lift LTG shows a change greater than a reference value $\Delta L3$ in a period $t4$ starting from $t0$ at which the target lift starts to change, where each target lift LTG is calculated from the map stored in the ROM 12 according to an engine speed NE and a load PA. If there is a change greater than $\Delta L3$, step 202 is carried out, and if not, the routine ends. Step 202 determines whether or not a real lift LR detected by the lift sensor 30 is equal to " $L0 + \Delta L3$," where $L0$ is a real lift at $t0$. If step 202 provides YES, step 203 is carried out, and if not, the routine ends. Step

203 reads a period $t5$ which starts at $t0$ and ends when the real lift LR that is equal to " $L0 + \Delta L3$ " is detected by the lift sensor 30. Step 204 compares the period $t5$ with a reference value $t6$. If $t5 > t6$, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 205 is carried out. If $t5 \leq t6$, the valve 9 and sensor 30 are sound, and the routine ends. Step 205 turns on the alarm lamp 28, and the routine ends.

Figure 7 is a flowchart showing a fourth routine of diagnosing the EGR control valve 9, and Fig. 8 is a graph showing lift in the EGR control valve 9 based on the fourth routine. In Fig. 8, an abscissa represents time, an ordinate represents lift, a continuous curve represents target lift that starts to change at $t0$, a dotted curve represents real lift, and a dot-and-dash line represents duty factors applied to the coil 51 of the vacuum switching valve 50.

Step 301 determines whether or not a target lift LTG, which is calculated from the map stored in the ROM 12 according to an engine speed NE and a load PA, is between a closed level (0 mm) and a full-open level (LMAX mm) of the EGR control valve 9. If step 301 provides YES, step 302 is carried out, and if not, the routine ends. Step 302 determines whether or not the difference " $LTG - LR$ " is greater than a reference value $\Delta L4$, where LR is a real lift detected after a period $t7$ starting from $t0$ and LTG is a corresponding target value. If step 302 provides YES, step 303 is carried out, and if not, the routine ends. Step 303 provides an ON/OFF signal, i.e., a duty signal representing a duty factor of 100% from the drive circuit 26 to the coil 51 of the vacuum switching valve 50. Step 304 determines whether or not the difference " $LTG - LR$ " between a real lift LR detected after the duty factor of the valve 50 has been set to 100% and a corresponding target lift LTG is smaller than $\Delta L4$. If step 304 provides YES, step 305 is carried out, and if not, step 308 is carried out. Step 305 reads a period $t8$ which starts at $t0$ and ends when step 304 determines that the difference " $LTG - LR$ " becomes smaller than $\Delta L4$, and resets the duty factor of the valve 50 to the previous setting before being set to 100%. Step 306 calculates a continuation period " $t8 - t7$ " for which the duty factor of the valve 50 has been kept at 100% and compares it with a reference value $t9$. If $t8 - t7 > t9$, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 307 is carried out. If $t8 - t7 \leq t9$, the valve 9 and sensor 30 are sound, and the routine ends. Step 307 turns on the alarm lamp 28, and the routine ends. Step 308 determines whether or not a period counted from $t0$ is greater than the reference value $t9$. If so, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 307 is carried out, and if not, the routine ends.

Figure 9 is a flowchart showing a fifth routine of diagnosing the EGR control valve 9, and Fig. 10 is a graph showing lifts in the EGR control valve 9 based on the fifth routine. In Fig. 10, an abscissa represents time, an ordinate represents lifts, a continuous curve repre-

sents a target lift that starts to change at time t_0 , a dotted curve represents real lift, and a dot-and-dash line represents duty factors applied to the coil 51 of the vacuum switching valve 50.

Step 401 determines whether or not a target lift LTG, which is calculated from the map stored in the ROM 12 according to an engine speed NE and a load PA, is between a closed level (0 mm) and a full-open level (LMAX mm) of the EGR control valve 9. If step 401 provides YES, step 402 is carried out, and if not, the routine ends. Step 402 determines whether or not the difference "LR - LTG" is greater than a reference value $\Delta L5$, where LR is a real lift detected after a period t_{10} starting from t_0 and LTG is a corresponding target value. If step 402 provides YES, step 403 is carried out, and if not, the routine ends. Step 403 provides an ON/OFF signal, i.e., a duty signal representing a duty factor of 0% from the drive circuit 26 to the coil 51 of the vacuum switching valve 50. Step 404 determines whether or not the difference "LR - LTG" between a real lift LR detected after the duty factor of the valve 50 has been set to 0% and a corresponding target lift LTG is smaller than $\Delta L5$. If step 404 provides YES, step 405 is carried out, and if not, step 408 is carried out. Step 405 reads a period t_{11} which starts at t_0 and ends when step 404 determines that the difference "LR - LTG" becomes smaller than $\Delta L5$, and releases the 0% duty factor from the valve 50. Step 406 calculates a continuation period " $t_{11} - t_{10}$ " for which the duty factor of the valve 50 has been kept at 0% and compares it with a reference value t_{12} . If $t_{11} - t_{10} > t_{12}$, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 407 is carried out. If $t_{11} - t_{10} \leq t_{12}$, the valve 9 and sensor 30 are sound, and the routine ends. Step 407 turns on the alarm lamp 28, and the routine ends. Step 408 determines whether or not a period counted from t_0 is greater than the reference value t_{12} . If so, the EGR control valve 9 or the lift sensor 30 is abnormal, and step 407 is carried out, and if not, the routine ends.

If any one of steps 302 and 402 in the fourth and fifth routines of Figs. 7 to 10 provides NO due to, for example, a fuel cut, steps 303 to 308 or steps 403 to 408 may forcibly be carried out to determine whether or not the EGR control valve 9 is sound.

As explained above, the present invention determines whether or not the EGR system including the EGR control valve is sound according to the responsiveness of the EGR control valve with respect to target apertures of the EGR control valve, instead of comparing a real aperture of the EGR control valve with a specific target aperture thereof that is determined based on engine operating conditions. After the EGR conditions are met and when a target aperture of the EGR control valve shows a change greater than a predetermined magnitude, the present invention detects a real aperture of the EGR control valve with the use of the aperture detector, and if the real aperture does not follow the change in the target apertures, determines that the

EGR system including the EGR control valve is abnormal. Consequently, the present invention is capable of correctly determining whether or not the EGR control valve is sound without regard to fluctuations in the characteristics of the negative pressure setter for setting a negative pressure applied to the EGR control valve or the aging of the negative pressure setter.

It will be understood by those skilled in the art that the foregoing descriptions are preferred embodiments of the disclosed apparatus and that various changes and modifications may be made to the invention without departing from the spirit and scope thereof.

An exhaust gas recirculation (EGR) system for an internal combustion engine is capable of correctly determining whether or not an EGR control valve (9) is sound, irrespective of variations in the characteristics of a unit for setting a negative pressure applied to the EGR control valve or the aging of the unit.

The EGR system has the EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1), for controlling the flow rate of exhaust gas recirculated through the recirculation path (8), an aperture detector for detecting a real aperture of the EGR control valve (9) at proper intervals, a driver for driving the EGR control valve (9) in a way to provide a target aperture that is set at proper intervals according to operating conditions of the engine (1), and a diagnostic unit that determines that the EGR system including the EGR control valve (9) is abnormal if real apertures detected by the aperture detector do not follow corresponding target apertures after the target apertures show a change of predetermined magnitude.

Claims

1. An exhaust gas recirculation system of an internal combustion engine, comprising

an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path,

detection means (30) for detecting a real aperture of the EGR control valve at proper intervals and

drive means (50) for driving the EGR control valve in a way to provide a target aperture that is set at proper intervals according to operating conditions of the engine characterized in that said system comprises:

diagnostic means (10) for determining that the exhaust gas recirculation system including the EGR control valve is abnormal if real apertures detected by the detection means do not follow corresponding target apertures after target apertures set according to operating conditions

of the engine show a change of predetermined magnitude.

2. The exhaust gas recirculation system of claim 1, wherein said diagnostic means determines that the exhaust gas recirculation system including the EGR control valve is abnormal if a first period, which starts at the start of the change of predetermined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with a corresponding target aperture, is greater than a first reference value. 5
3. The exhaust gas recirculation system of claim 1, wherein said diagnostic means determines that the exhaust gas recirculation system including the EGR control valve is abnormal if a second period, which starts at the start of the change of predetermined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with a second target aperture that is set a given period after the start of the change of predetermined magnitude in target apertures, is greater than a second reference value. 10 15 20
4. The exhaust gas recirculation system of claim 1, wherein said diagnostic means maximizes, if a real aperture of the EGR control valve is smaller than a corresponding target aperture and if the difference between them is greater than a reference difference, the target aperture of the EGR control valve for a first continuation period until the difference between real and target apertures agrees with the reference difference, and determines that the EGR system including the EGR control valve is abnormal if the first continuation period is greater than a third reference value. 25 30 35
5. The exhaust gas recirculation system of claim 1, wherein said diagnostic means minimizes, if a real aperture of the EGR control valve is greater than a corresponding target aperture and if the difference between them is greater than a reference difference, the target aperture of the EGR control valve for a second continuation period until the difference between real and target apertures agrees with the reference difference, and determines that the exhaust gas recirculation system including the EGR control valve is abnormal if the second continuation period is greater than a fourth reference value. 40 45 50
6. A method of detecting an abnormality in an exhaust gas recirculation system of an internal combustion engine, said system having an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path, the 55

EGR control valve being controlled to provide a target aperture that is set at proper intervals according to operating conditions of the engine, said method comprising the steps of:

- detecting a change of predetermined magnitude in a given period in target apertures set for the EGR control valve;
- detecting a real aperture of the EGR control valve at proper intervals after the start of the change of predetermined magnitude detected in target apertures;
- determining whether or not the difference between the detected real aperture and a corresponding target aperture is smaller than the change of predetermined magnitude; and
- determining that the exhaust gas recirculation system including the EGR control valve is abnormal if the difference is not smaller than the change of predetermined magnitude.
7. A method of detecting an abnormality in an exhaust gas recirculation system of an internal combustion engine, said system having an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path, the EGR control valve being controlled to provide a target aperture that is set at proper intervals according to operating conditions of the engine, said method comprising the steps of:
 - detecting a change of predetermined magnitude in a given period in target apertures set for the EGR control valve;
 - detecting a real aperture of the EGR control valve at proper intervals after the start of the change of predetermined magnitude detected in target apertures;
 - measuring a first period which starts at the start of the change of predetermined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with a corresponding target aperture; and
 - determining that the exhaust gas recirculation system including the EGR control valve is abnormal if the first period is greater than a first reference value.
8. A method of detecting an abnormality in an exhaust gas recirculation system of an internal combustion engine, said system having an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path, the

EGR control valve being controlled to provide a target aperture that is set at proper intervals according to operating conditions of the engine, said method comprising the steps of:

5 detecting a change of predetermined magnitude in a given period in target apertures set for the EGR control valve;
 detecting a real aperture of the EGR control valve at proper intervals after the start of the change of predetermined magnitude detected in target apertures;
 10 reading a second target aperture that is set a given period after the start of the change of predetermined magnitude in target apertures;
 detecting a real aperture of the EGR control valve at proper intervals;
 15 measuring a second period which starts at the start of the change of predetermined magnitude in target apertures and ends when a real aperture of the EGR control valve substantially agrees with the second target aperture; and
 20 determining that the exhaust gas recirculation system including the EGR control valve is abnormal if the second period is greater than a second reference value.

9. A method of detecting an abnormality in an exhaust gas recirculation system of an internal combustion engine, said system having an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (12) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path, the EGR control valve being controlled to provide a target aperture that is set at proper intervals according to operating conditions of the engine, said method comprising the steps of:

40 detecting a change of predetermined magnitude in a given period in target apertures set for the EGR control valve;
 detecting a real aperture of the EGR control valve at proper intervals after the start of the change of predetermined magnitude detected in target apertures;
 45 maximizing the target aperture of the EGR control valve if a real aperture of the EGR control valve is smaller than a corresponding target aperture and if the difference between them is greater than a reference difference;
 50 keeping the target aperture of the EGR control valve at the maximum until the difference between real and target apertures agrees with the reference difference;
 55 measuring a first continuation period in which the target aperture of the EGR control valve has been kept at the maximum; and

determining that the exhaust gas recirculation system including the EGR control valve is abnormal if the first continuation period is greater than a third reference value.

10. A method of detecting an abnormality in an exhaust gas recirculation system of an internal combustion engine, said system having an EGR control valve (9) disposed in a recirculation path (8) that connects an exhaust path (2) to an intake path (3) of the engine (1) and controls the flow rate of exhaust gas recirculated through the recirculation path, the EGR control valve being controlled to provide a target aperture that is set at proper intervals according to operating conditions of the engine, said method comprising the steps of:

detecting a change of predetermined magnitude in a given period in target apertures set for the EGR control valve;
 detecting a real aperture of the EGR control valve at proper intervals after the start of the change of predetermined magnitude detected in target apertures;
 minimizing the target aperture of the EGR control valve if a real aperture of the EGR control valve is greater than a corresponding target aperture and if the difference between them is greater than a reference difference;
 keeping the target aperture of the EGR control valve at the minimum until the difference between real and target apertures agrees with the reference difference;
 measuring a second continuation period in which the target aperture of the EGR control valve has been kept at the minimum; and
 determining that the exhaust gas recirculation system including the EGR control valve is abnormal if the second continuation period is greater than a fourth reference value.

Fig.1

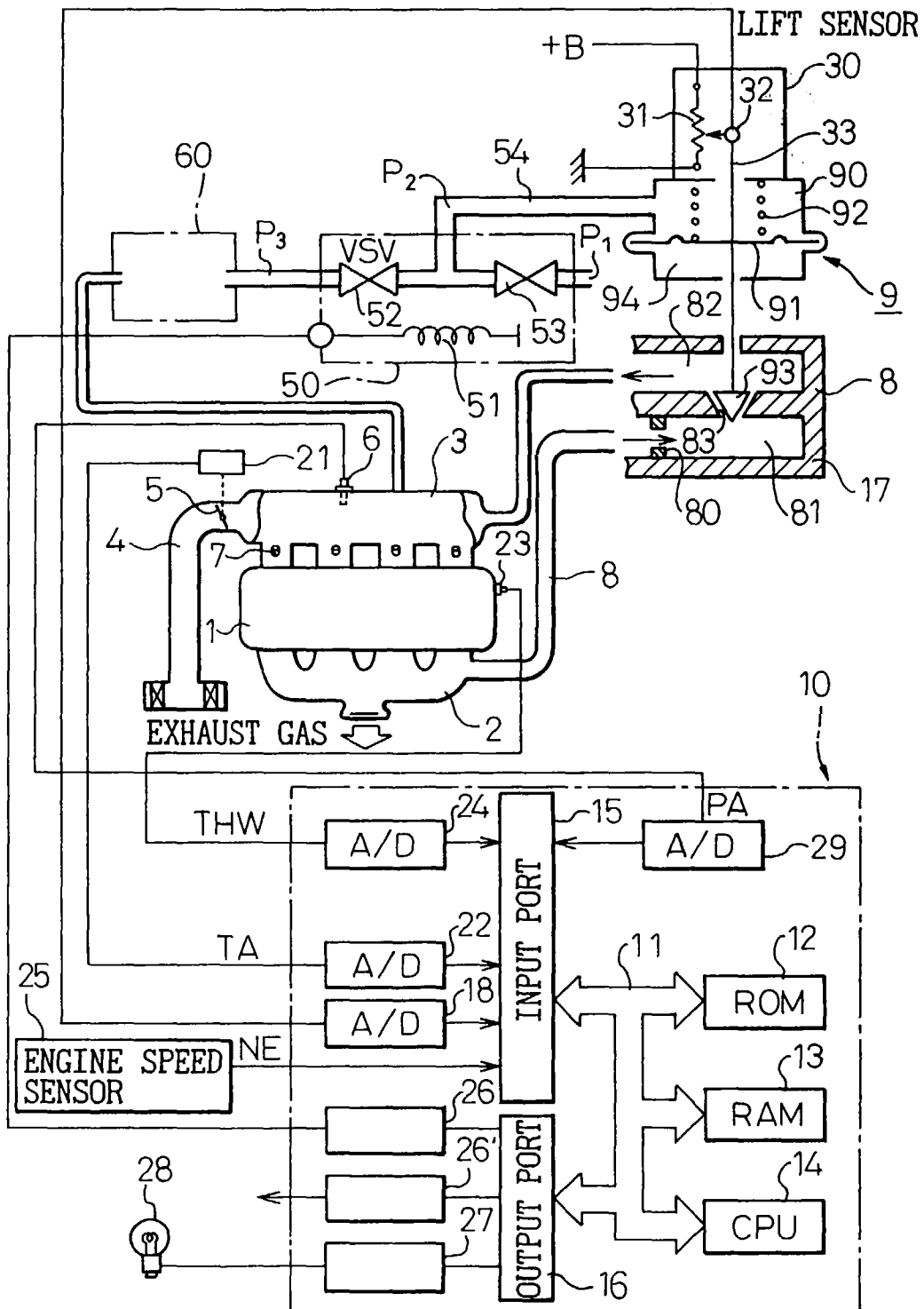


Fig. 2

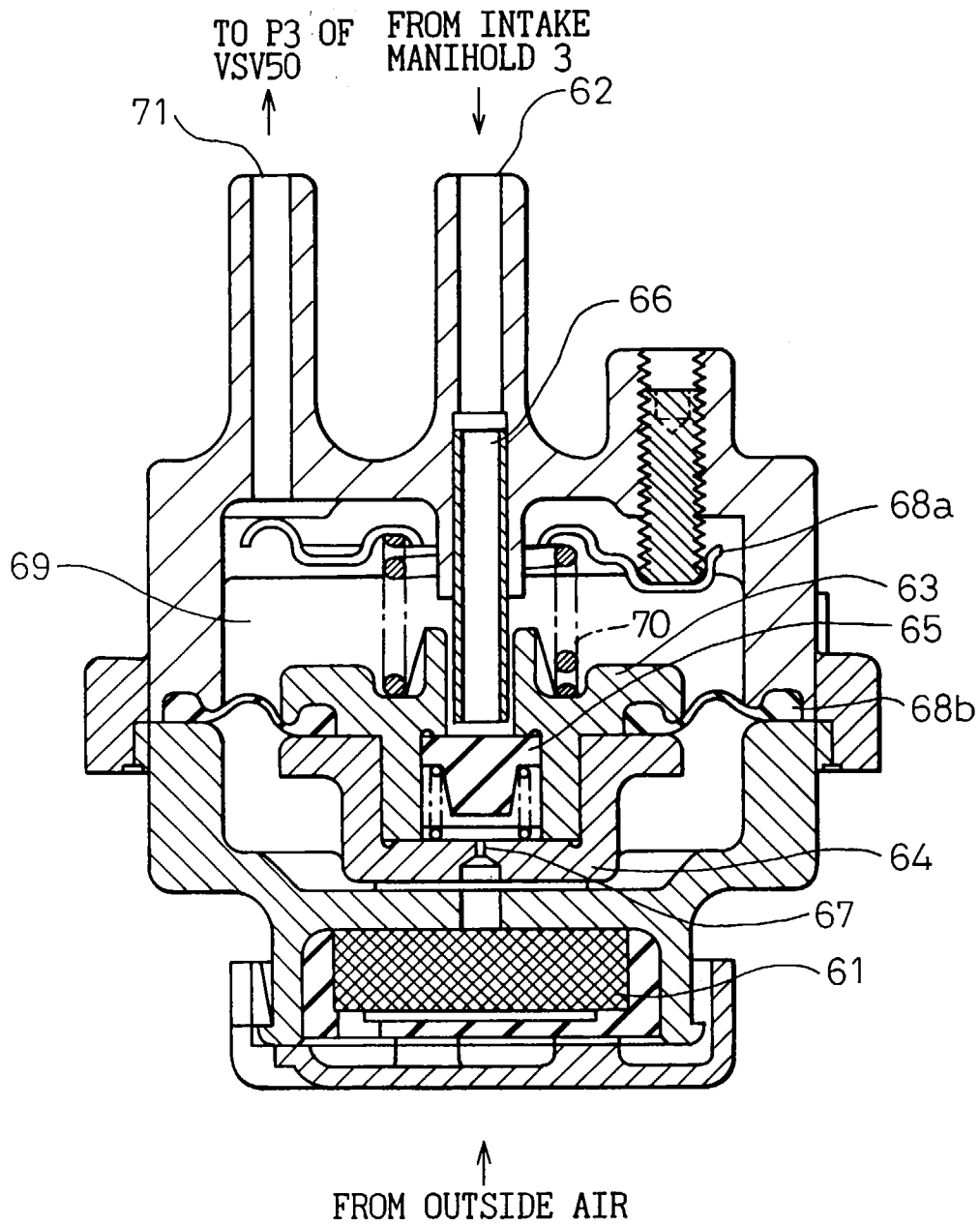


Fig. 3A

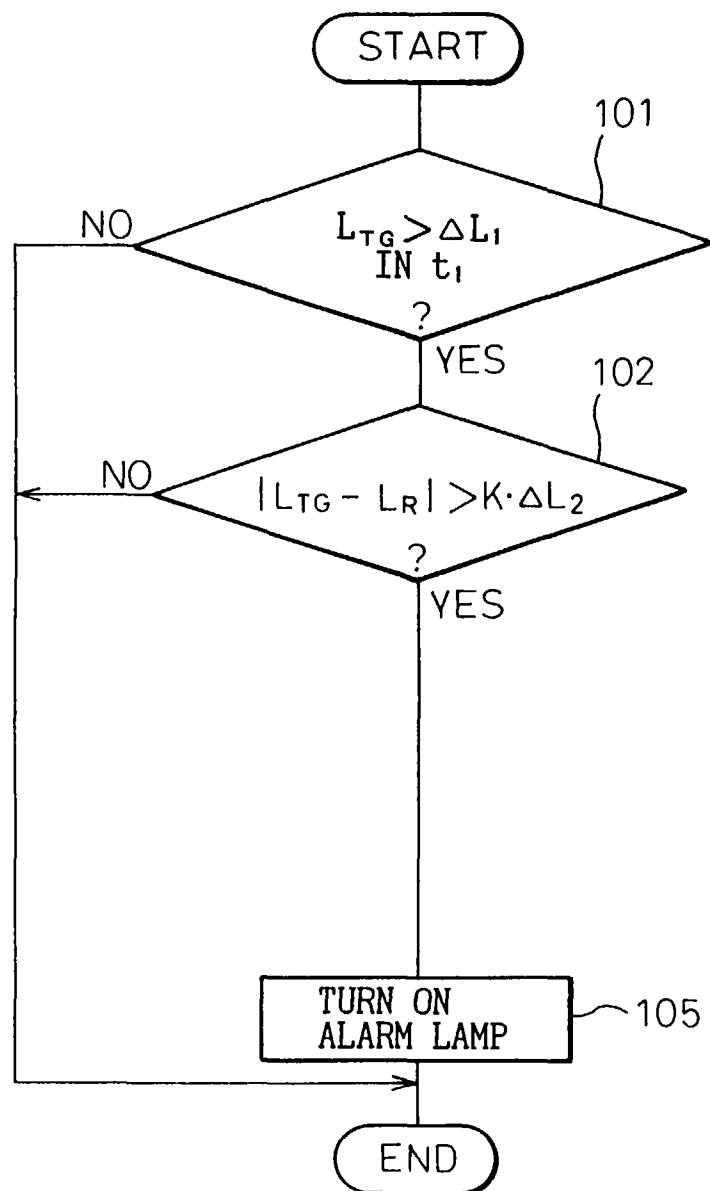


Fig.3B

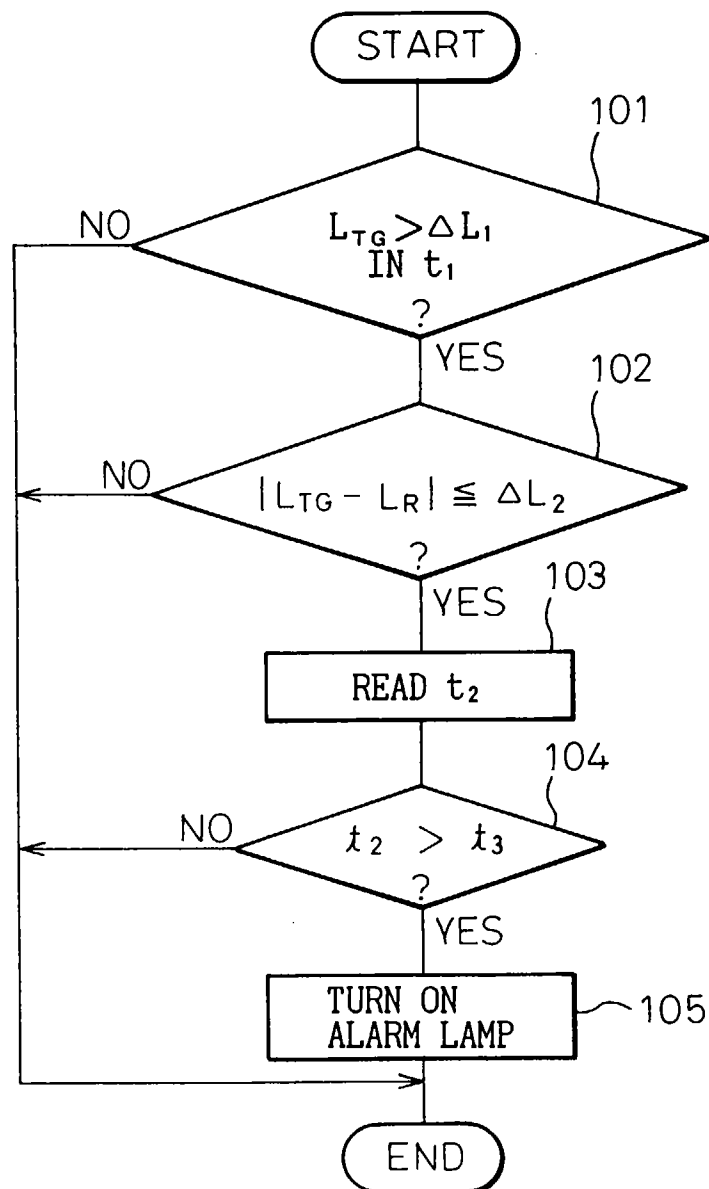


Fig.4

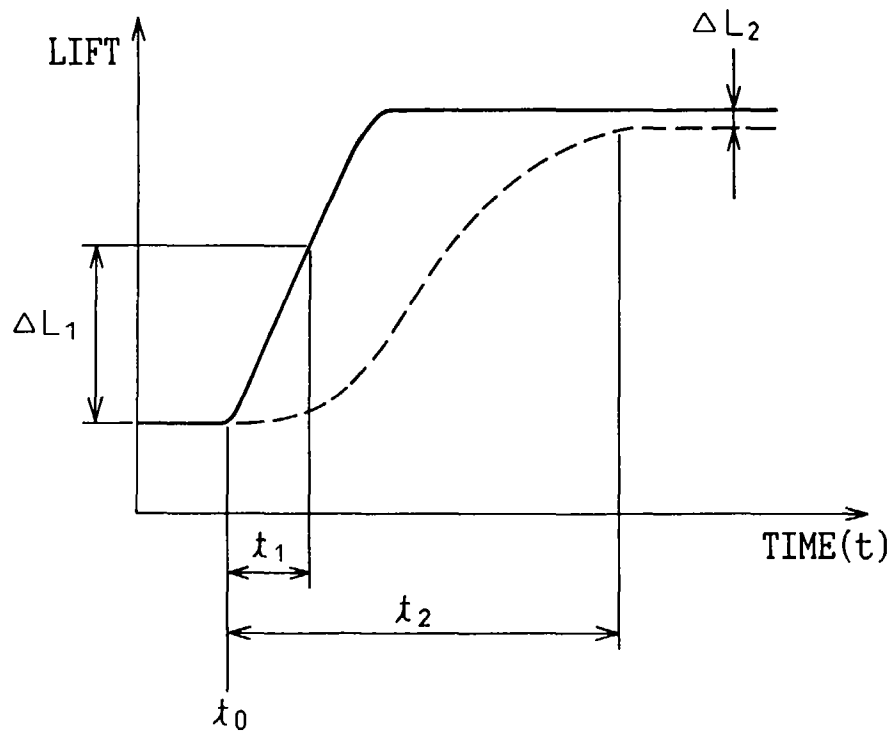


Fig.5

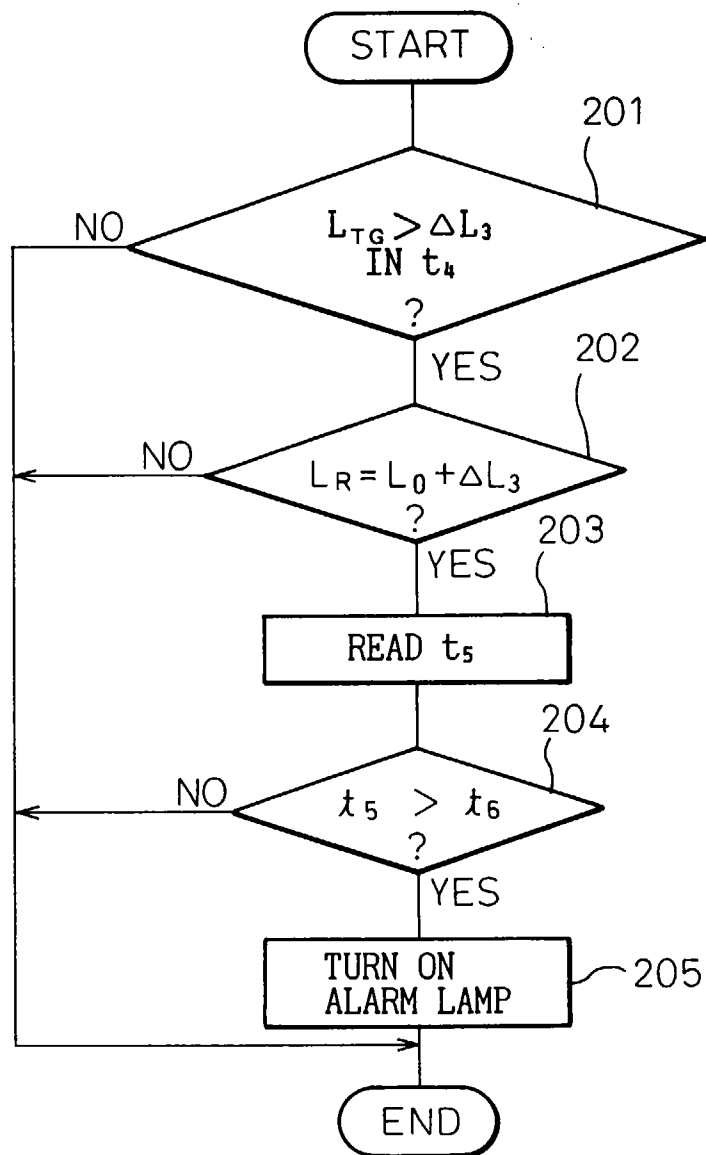


Fig. 6

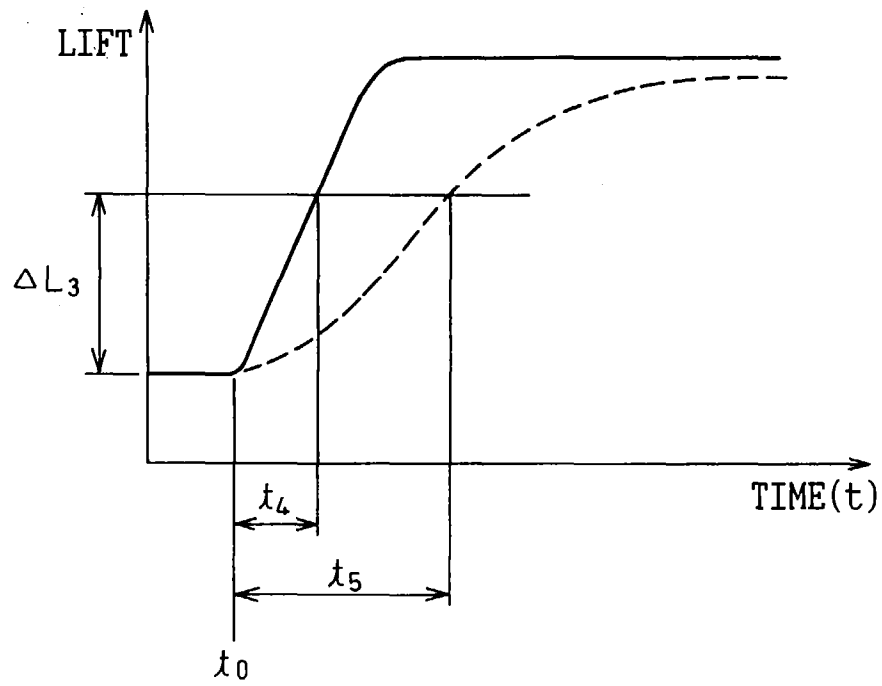


Fig.7

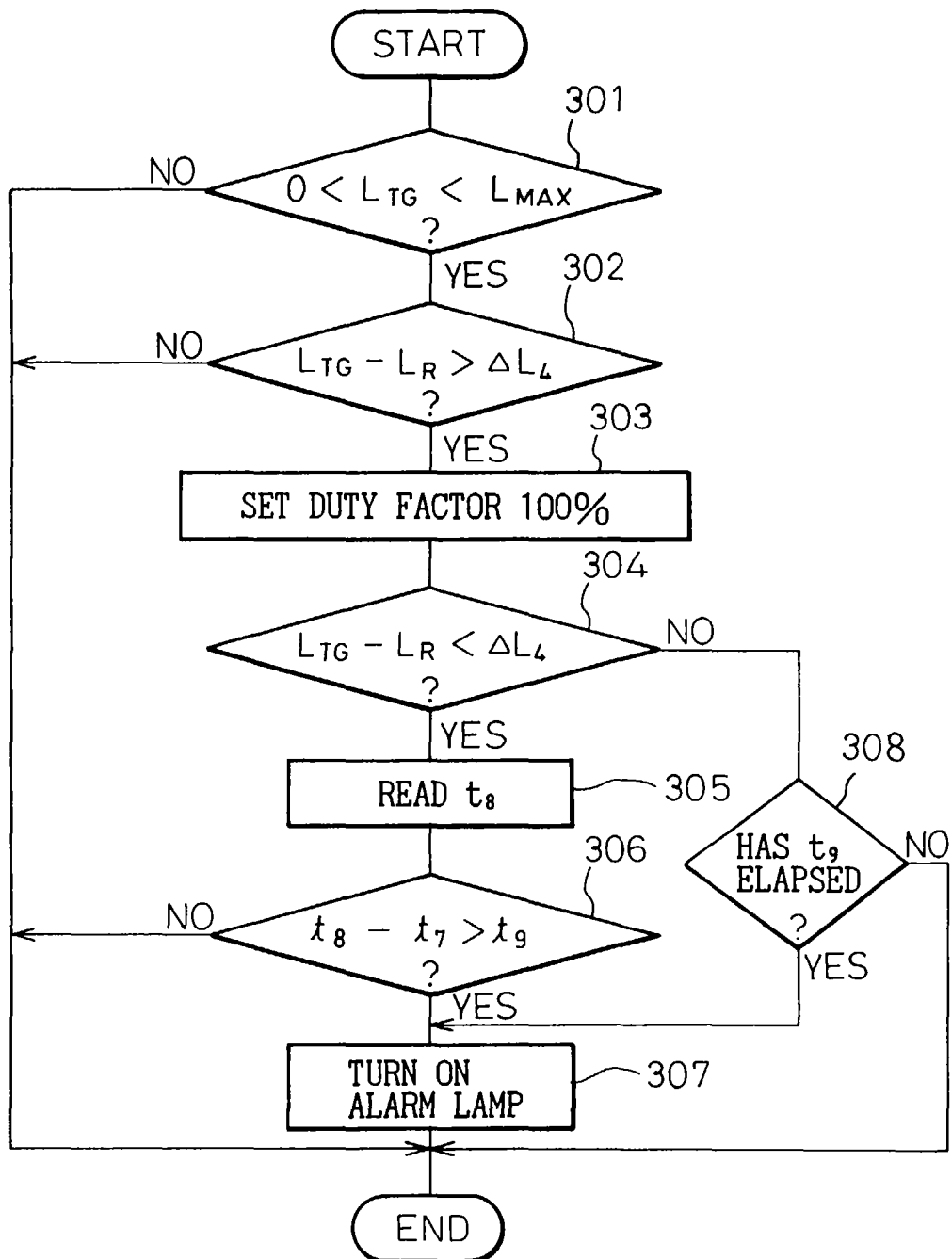


Fig.8

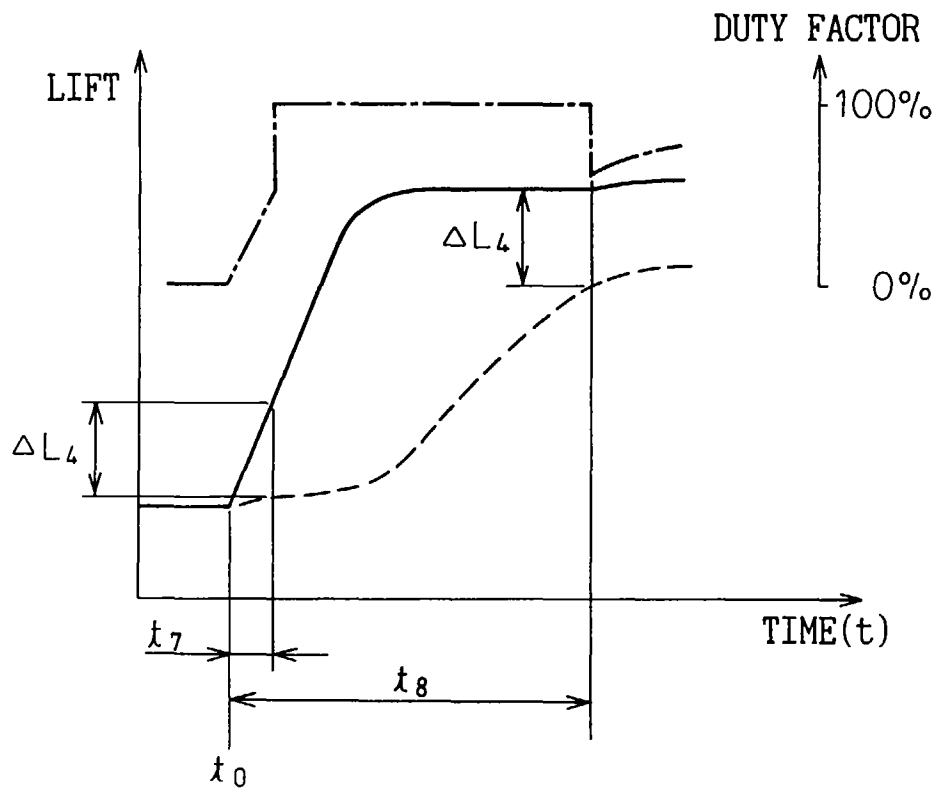


Fig.9

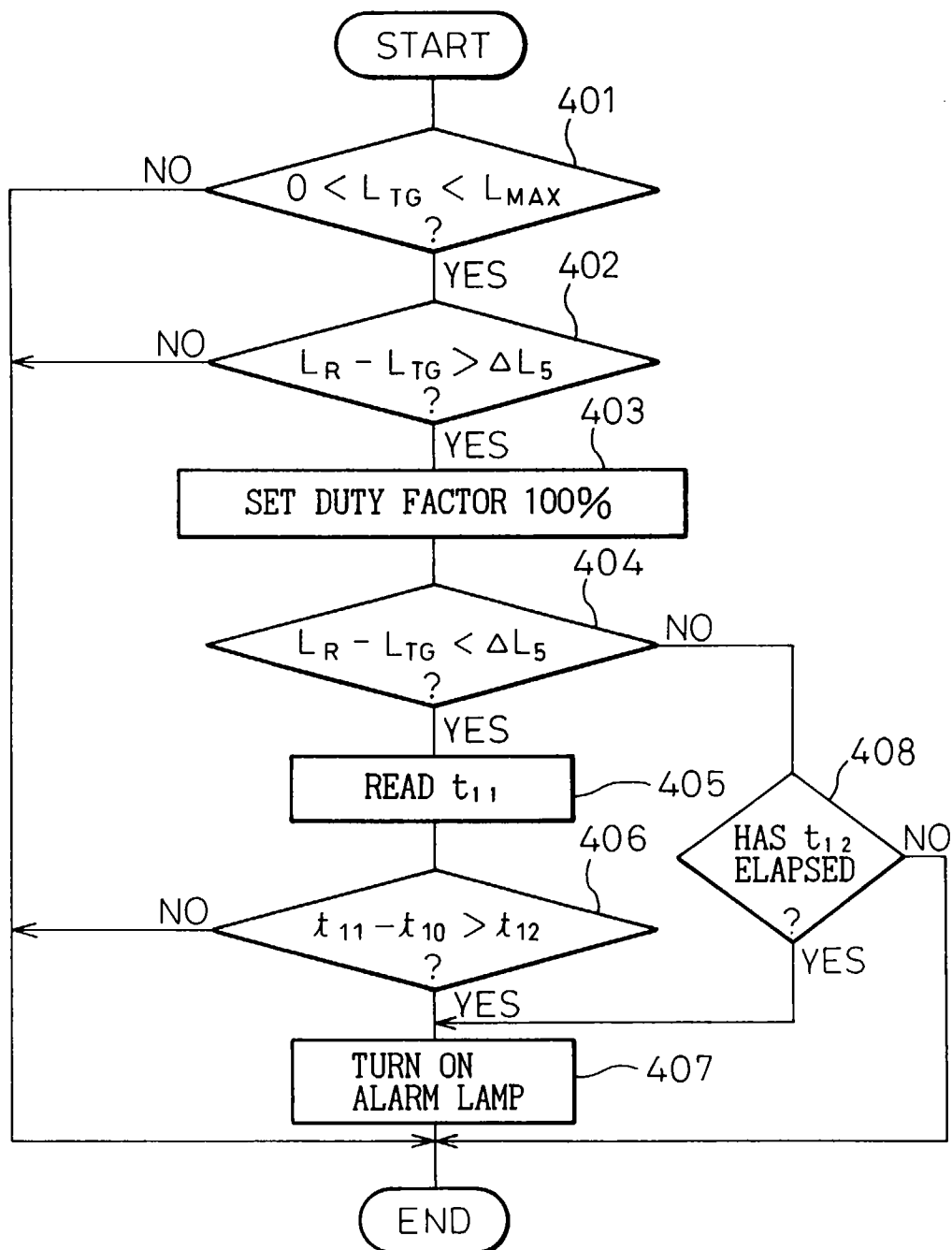


Fig.10

