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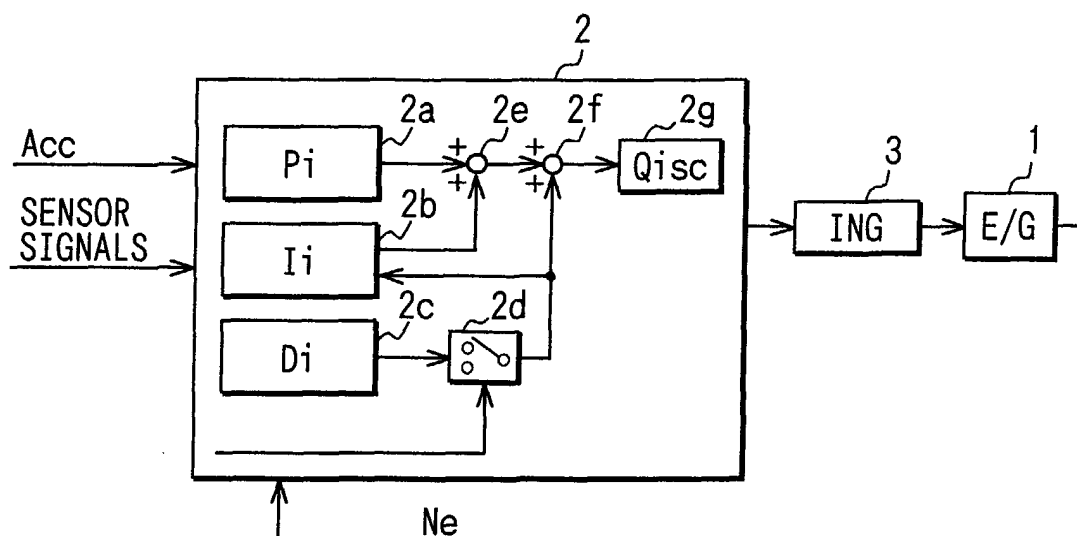
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(54) **Method for controlling idling speed of internal combustion engine**

(57) If the driver takes foot off the accelerator while the running condition of the vehicle, an engine speed decreases to a target engine speed for an idling condition. A corrective injection amount is calculated and added on a base injection amount when the engine speed is in a vicinity of the target engine speed ($Ne_{isc} + \Delta N2 \leq Ne < Ne_{isc} + \Delta N1$). The corrective injection amount is calculated based on a decreasing speed dNe/dt of the

Ne . The corrective amount is gradually increased by an affecting ratio coefficient Kdl so that 100 % of the corrective amount is fully effective when the engine speed Ne coincides with the target engine speed Ne_{isc} . As a result, it is possible to suppress a decreasing speed of the engine speed. It is possible to prevent the engine speed from an excessive drop with respect to the target engine speed. It is possible to approach the engine speed smoothly to the target engine speed.

FIG. 1



Description

[0001] The present invention relates to a method for controlling an idling speed of an internal combustion engine in which an injection amount is controlled by a feedback method so as to keep a target engine speed when a vehicle runs under an idling condition after a driver takes his or her foot off an accelerator while the vehicle runs.

[0002] An idling speed of an engine becomes stable at a rotating speed where a generated torque of the engine and a load torque caused by a friction in the engine itself balance. For example, if temperature is low, the idling speed is lowered since the friction in the engine itself is increased resulted from an increased viscosity of the engine lubricant oil. However, if the idling speed is lowered, the engine speed gets unstable, therefore there is a possibility that the driver get an uncomfortable feeling. On the other hand, if the idling speed is too high, the engine noise may be increased and the fuel economy may be lowered.

[0003] To avoid above disadvantages, it is proposed that a method for controlling the injection amount to a value that is necessary to keep the target idling speed even if the load torque of the engine is changed. That is called as an idling speed control.

[0004] For example, in the idling speed control for an diesel engine, an actual engine speed and a target engine speed obtained based on conditions such as a engine cooling water temperature and a load of a compressor for an air conditioner, and the injection amount is controlled by a PI type feedback method so that the target engine speed is achieved in accordance with a difference between those of the engine speeds.

[0005] However, according to the conventional idling speed control, when a driver takes foot off an accelerator in a running condition of a vehicle and runs the vehicle under an idling condition, the actual engine speed may repeat overshoots until the actual engine speed N_e convergences to the target engine speed N_{isc} . The repeated overshoots are triggered by insignificant hunting oscillations caused by the PI type feedback control, and causes a disadvantage that the driver may have unevenness about a drive feeling.

[0006] The present invention was accomplished in consideration of the above-mentioned circumstances, it is an object of the present invention to provide a method for controlling an idling speed of an internal combustion engine, which is capable of approaching the actual engine speed to the target engine speed smoothly during the idling speed control executed when the vehicle runs under the idling condition after the driver takes foot off the accelerator while running the vehicle.

[0007] The method for controlling the idling speed of the present invention is characterized by executing an injection correcting control for correcting the injection amount in order to suppress an excessive drop of the engine speed (decreasing speed) caused by a feedback

control of the injection amount in accordance with a difference between an actual engine speed and a target engine speed.

[0008] Accordingly, it is possible to prevent the actual engine speed from the excessive drop with respect to the target engine speed, and to approaches the actual engine speed smoothly to the target engine speed.

[0009] The injection correcting control may comprises a step of calculating a corrective injection amount based on a decreasing speed of the engine speed. It is possible to suppress a decreasing speed of the engine speed relative to a decreasing speed caused by injecting a usual injection amount.

[0010] The injection correcting control may comprises a step of gradually increasing the corrective injection amount as the actual engine speed approaches to the target engine speed when the actual engine speed closely approaches to the target engine speed so that 100 % of the corrective injection amount affects the engine speed. It is possible to prevent the engine speed from an excessive quick deviation, and the driver is prevented from an uncomfortable shock feeling.

[0011] The corrective injection amount may be different with respect to an engine load. It is possible to execute the injection correcting control appropriately by varying the corrective injection amount in accordance with the engine load, e.g. the corrective injection amount is increased as the gear ratio is increased.

[0012] Features and advantages of embodiments will be appreciated, as well as methods of operation and the function of the related parts, from a study of the following detailed description, the appended claims, and the drawings, all of which form a part of this application. In the drawings:

FIG. 1 is a control block diagram according to an embodiment of the present invention;

FIG. 2 is a flowchart showing a base routine of the embodiment;

FIG. 3 is a flowchart showing a subroutine of the embodiment;

FIG. 4 is a flowchart showing a subroutine of the embodiment;

FIG. 5 is a graph showing flags corresponding to an engine speed;

FIG. 6 is graph showing an affecting ratio coefficient $Kd1$;

FIG. 7 is a map showing a relationship among a load and a coefficient $Kd2$; and

FIG. 8 is a graph showing behaviors of the engine speed.

[0013] Hereinafter, an embodiment of the present invention is described with reference to drawings.

[0014] FIG. 1 is a control block diagram of the embodiment, FIGS. 2 through 4 are flowcharts showing processing order of an ECU which executes an idling speed control.

[0015] For instance, in this embodiment, the idling speed control is applied to a diesel engine 1. The idling speed control executes a feedback control of an injection amount by driving an injection device 3 via an Electronic Control Unit 2 so as to coincide an actual engine speed N_e with a target engine speed N_{isc} when a vehicle runs under an idling condition after a driver takes foot off an accelerator pedal while running a vehicle. That is, during the driver taking foot off the accelerator, an operating degree of the accelerator is 0. The ECU 2 inputs the operating degree of the accelerator and other sensor signals such as the engine speed N_e . The ECU 2 has a block 2a for obtaining a proportional component of an injection amount in accordance with a difference ($N_{isc} - N_e$) between the engine speed N_e and the target engine speed N_{isc} . The ECU 2 has a block 2b for obtaining an integral component of the injection amount in accordance with the difference. The ECU 2 also has a block 2c for obtaining a differential component of the injection amount in accordance with the decreasing speed of the engine speed. The ECU 2 has a switch block 2d for controlling the differential component in accordance with conditions of the vehicle and the engine. The ECU 2 has adding blocks 2e and 2f for adding the components to obtain a conclusive corrective injection amount Q_{isc} . The ECU 2 has a block 2g for calculating a base injection amount Q_{base} for maintaining the engine rotation in accordance with the operating degree of the accelerator and the engine speed, for calculating a conclusive injection amount Q by summing the base injection amount Q_{base} and the conclusive corrective injection amount Q_{isc} , and for controlling the injection device 3 so as to inject and supply the conclusive injection amount Q to the engine 1.

[0016] A processing order of the idling speed control with the ECU 2 is explained with reference to a base routine shown in FIG. 2 and subroutines shown in FIGS. 3 and 4. Hereinafter, functions of each step are explained step by step.

[0017] In a step 100, a corrective amount P_i for P term, proportional component, is calculated by the following expression (1). In this embodiment, the corrective amount P_i is calculated as a base injection amount for an idling speed control.

$$P_i = K_p \cdot (N_{isc} - N_e) \quad (1)$$

[0018] In a step 200, corrective amounts I_i and D_i for I and D terms, integral and differential components, are calculated and read into the main routine.

[0019] In a step 300, a conclusive corrective injection amount Q_{isc} is calculated by summing the corrective amounts P_i , I_i and D_i .

[0020] Next, a process in the step 200 is explained.

[0021] In a step 201, it is determined that whether an initial process is completed or not. In the initial process, for instance, it is determined that whether an engine-

starting switch (an ignition key) is turned on or not. If the engine-starting switch is turned on (YES) the process proceeds to a step 202, if the engine-starting switch is already turned on (NO) the process proceeds to a step 203.

[0022] In a step 202, initial values are set to flags for showing conditions of the vehicle used in the process as follows: an ISC executing flag $F_0 = 1$, a running condition flag $F_1 = 0$, and a D term correction flag $F_2 = 0$.

[0023] In steps 203 through 210, conditions of the vehicle are determined into three categories as shown in FIG. 5.

[0024] In a step 203, a value of the flag F_2 is identified. If $F_2 = 1$ (YES), the process proceeds to the step 204, if $F_2 = 0$ (NO), the process proceeds to the step 206.

[0025] In a step 204, it is determined that whether the following EVENT A is satisfied or not. EVENT A: $N_e < N_{isc} + \Delta N_2$, or the driver takes foot off the accelerator and N_e is not changed (is stable). Here, ΔN_2 is a threshold value to determine whether the correction of D term should be stopped or not as shown in FIG. 5. If the EVENT A is satisfied (YES) the process proceeds to the step 205, if it is not satisfied (NO) the process proceeds to the step 208.

[0026] In a step 205, in this case, since the engine speed N_e is decreased from a D term correction region II to an ISC region I, the process proceeds to a step 211 after setting the flags as follows: the ISC executing flag $F_0 = 1$, $F_1 = 1$, $F_2 = 0$.

[0027] In a step 206, a value of the flag F_1 is identified. If $F_1 = 1$ (YES) the process proceeds to the step 207, if the $F_1 = 0$ (NO) the process proceeds to the step 209.

[0028] In a step 207, it is determined that whether the following EVENT B is satisfied or not. EVENT B: $N_e < N_{isc} + \Delta N_1$. Here ΔN_1 is a threshold value to determine whether the D term correction should be executed or not as shown in FIG. 5. If the EVENT B is satisfied (YES) the process proceeds to the step 208, if it is not satisfied (NO) the process proceeds to the step 210.

[0029] In a step 208, in this case, since the engine speed N_e is decreased from a running region III to the D term correction region II as shown in FIG. 5, the process proceeds to a step 211 after setting the flags as follows: the D term correction executing flag $F_2 = 1$, $F_0 = 0$, $F_1 = 0$.

[0030] In a step 209, it is determined that whether the following EVENT C is satisfied or not. EVENT C: $N_e \geq N_{isc} + \Delta N_1$. If the EVENT C is satisfied (YES) the process proceeds to the step 210, if the EVENT C is not satisfied (NO) the process proceeds to the step 205. Here, the ΔN_1 is a greater value than the ΔN_2 .

[0031] In a step 210, in this case, since the engine speed (N_e) is increased from the ISC region I to the running region III as shown in FIG. 5, the process proceeds to a step 211 after setting the flags as follows: the running condition flag $F_1 = 1$, $F_0 = 0$, $F_2 = 0$.

[0032] Next, the corrective amounts I_i and D_i for the I term and the D term are calculated in accordance with

the running condition of the engine.

[0033] In a step 211, a value of the flag F2 is identified. If F2 = 1 (YES) the process proceeds to a step 212, if F2 = 0 (NO) the process proceeds to a step 214. In a step 212, a differential component is calculated. The step 212 is activated only when the engine speed is approaching to the target engine speed and the engine speed is within a predetermined range. In the step 212, the process proceeds to a step 213 after calculating the corrective amount Di for the D term by the following expression (2).

$$Di = Kd \cdot dNe/dt \quad (2)$$

Kd: coefficient (affecting ratio coefficient), dNe/dt: decreasing speed of the Ne.

[0034] Here, it is necessary to be effective the corrective amount smoothly as the actual engine speed Ne approaches to the target engine speed Neisc, since if all (100 %) of the calculated corrective amount Di for D term is injected at once the engine speed quickly deviates and the driver may feel an uncomfortable shock. Therefore, the coefficient Kd is obtained as the product of a coefficient Kd1 and Kd2 as shown in FIGS. 6 and 7. The coefficient Kd1 is obtained based on a difference between the Ne and the Neisc. The coefficient Kd1 is set to increase the corrective amount gradually so as to affect 100 % of the corrective amount for Di term when the engine speed Ne coincides with the target engine speed Neisc. The coefficient Kd2 is determined by parameters such as an engine load as shown in FIG. 7, if the vehicle runs on a flat road and is in a constant temperature condition. The load may be obtained by a signal from a transmission indicative of gear positions. For example, it is necessary to increase torque generated by the engine 1 to obtain an even torque (deceleration) on a driving wheel as a gear position (ratio) is increased. Therefore, the corrective injection amount is also increased.

[0035] In a step 213, the process proceeds to a step 220 after replacing the corrective amount li-1 calculated in the last time with the present corrective amount li.

[0036] In a step 214, a value of the flag F0 is identified. If F0 = 1 (YES) the process proceeds to a step 215, if F0 = 0 (No) the process proceeds to a step 218. In a step 215, it is determined that whether the flag F0 = 1 is set in the present process or not. If the determination is YES the process proceeds to a step 216, if the determination is NO (the ISC control has been already executed) the process proceeds to a step 219.

[0037] In a step 216, the process proceeds to a step 217 after calculating the corrective amount li for the I term by the following expression (3).

$$li = li-1 + Di \quad (3)$$

[0038] In this step, the corrective amount Di calculated in the step 212 is added only when the flags are changed from F2 = 1 to F0 = 1, i.e. only when the corrective amount li is calculated for the first time. Accordingly, it is possible to suppress drop of the engine speed Ne when it is changed from the D term correction region II to the ISC executing region I, and to provide a smooth transition of the corrective amount.

[0039] In a step 217, the process proceeds to a step 220 after setting Di = 0. In this step, Di = 0 is set so that adding the corrective amount Di is substantially inhibited for a second or later calculation of the corrective amount li.

[0040] In a step 218, the process proceeds to the step 220 after calculating the corrective amount li by the following expression (4).

$$li = li-1 \quad (4)$$

[0041] In a step 210, the process proceeds to the step 220 after calculating the corrective amount li by the following expression (5).

$$li = li-1 + f(Neisc - Ne) \quad (5)$$

[0042] In a step 220, the corrective amounts li-1 and Di-1 calculated in the last time are replaced with the corrective amounts li and Di calculated in the present process.

(Advantages of the embodiment)

[0043] According to the embodiment, if the engine speed is decreased when the driver takes foot off the accelerator while the running condition of the vehicle, a corrective injection amount for correcting the injection amount is obtained on a vicinity of the target engine speed (Neisc + ΔN2 ≤ Ne < Neisc + ΔN1). Therefore, it is possible to suppress a decreasing speed of the engine speed relative to a conventional idling speed control using a PI type feedback control. Accordingly, it is possible to prevent the engine speed from an excessive drop (overshoot) with respect to the target engine speed. It is possible to approach the engine speed smoothly to the target engine speed as shown in FIG. 8 with a solid line. If the driver takes foot off the accelerator while the running condition of the vehicle, an engine speed decreases to a target engine speed for an idling condition. A corrective injection amount is calculated and added on a base injection amount when the engine speed is in a vicinity of the target engine speed (Neisc + ΔN2 ≤ Ne < Neisc + ΔN1). The corrective injection amount is calculated based on a decreasing speed dNe/dt of the Ne. The corrective amount is gradually increased by an affecting ratio coefficient Kd1 so that 100 % of the corrective amount is fully effective when the

engine speed N_e coincides with the target engine speed N_{isc} . As a result, it is possible to suppress a decreasing speed of the engine speed. It is possible to prevent the engine speed from an excessive drop with respect to the target engine speed. It is possible to approach the engine speed smoothly to the target engine speed.

Claims

1. A method for controlling an idling speed of an internal combustion engine (1), the method comprising the steps of:

controlling an injection amount by a feedback method so as to maintain a target engine speed when a vehicle runs under an idling condition after a driver takes foot off an accelerator while running a vehicle, **characterized in that** the injection amount is corrected (2b, 2c, 2e, 2f) in order to suppress an excessive drop of the engine speed that may be caused by a feedback control of the injection amount in accordance with a difference between an actual engine speed and a target engine speed.

2. The method for controlling the idling speed of the internal combustion engine according to claim 1, wherein the method comprising the steps of:

calculating (2a) a base injection amount (P_i) for an idling speed control in accordance with a difference ($N_{isc} - N_e$) between the actual engine speed and the target engine speed;
calculating (2b, 2c) a corrective injection amount (D_i) based on a decreasing speed (dN_e/dt) of the engine speed;
obtaining (2e, 2f) a conclusive injection amount (Q_{isc}) for the idling speed control by summing the base injection amount and the corrective injection amount.

3. The method for controlling the idling speed of the internal combustion engine according to claim 2, further comprising the step of gradually increasing (2c) the corrective injection amount (D_i) as the actual engine speed approaches to the target engine speed so that 100 % of the corrective injection amount affects the engine speed when the actual engine speed is substantially coincide with the target engine speed.

4. The method for controlling the idling speed of the internal combustion engine according to claim 2 or 3, wherein the corrective injection amount is different with respect to an engine load.

5. The method for controlling the idling speed of the

internal combustion engine according to one of claims 2 through 4, wherein the step of calculating (2c) the corrective injection amount (D_i) based on the decreasing speed (dN_e/dt) of the engine speed is activated only when the engine speed is approaching to the target engine speed and the engine speed is within a predetermined range ($N_{isc} + \Delta N_2 \leq N_e < N_{isc} + \Delta N_1$).

6. The method for controlling the idling speed of the internal combustion engine according to one of claims 2 through 5, wherein the method further comprising the steps of:

calculating a base injection amount (Q_{base}) for rotating the engine;
calculating a conclusive injection amount (Q) by summing the base injection amount (Q_{base}) and the conclusive injection amount (Q_{isc}) for the idling speed control; and
injecting the conclusive injection amount (Q) into the engine.

7. The method for controlling the idling speed of the internal combustion engine according to claim 1, wherein the method comprising the steps of:

calculating a base injection amount (Q_{base}) for rotating the engine;
calculating a proportional component (P_i) for executing an idling speed control based on a difference ($N_{isc} - N_e$) between the engine speed and the target engine speed;
calculating a conclusive injection amount (Q) by summing the base injection amount (Q_{base}) and the proportional component (P_i);
injecting the conclusive injection amount (Q) to the engine;
calculating a differential component (D_i) for executing an idling speed control based on a decreasing speed (dN_e/dt) of the engine speed;
calculating a conclusive injection amount (Q) by summing the base injection amount (Q_{base}), the proportional component (P_i) and the differential component (D_i) when the engine speed is within a predetermined range ($N_{isc} + \Delta N_2 \leq N_e < N_{isc} + \Delta N_1$) which is set slightly above the target engine speed; and
injecting the conclusive injection amount (Q) to the engine when the engine speed is within the predetermined range.

8. The method for controlling the idling speed of the internal combustion engine according to claim 7, wherein the differential component (D_i) is calculated so as to increase the differential component as the engine speed approaches to the target engine speed.

9. The method for controlling the idling speed of the internal combustion engine according to claim 7, wherein the differential component (Di) is calculated so as to affect 100 % of the differential component affects the idling speed control when the engine speed substantially coincide with the target engine speed. 5
10. The method for controlling the idling speed of the internal combustion engine according to claim 7, wherein the differential component (Di) is calculated so as to increase the differential component as an engine load increases. 10

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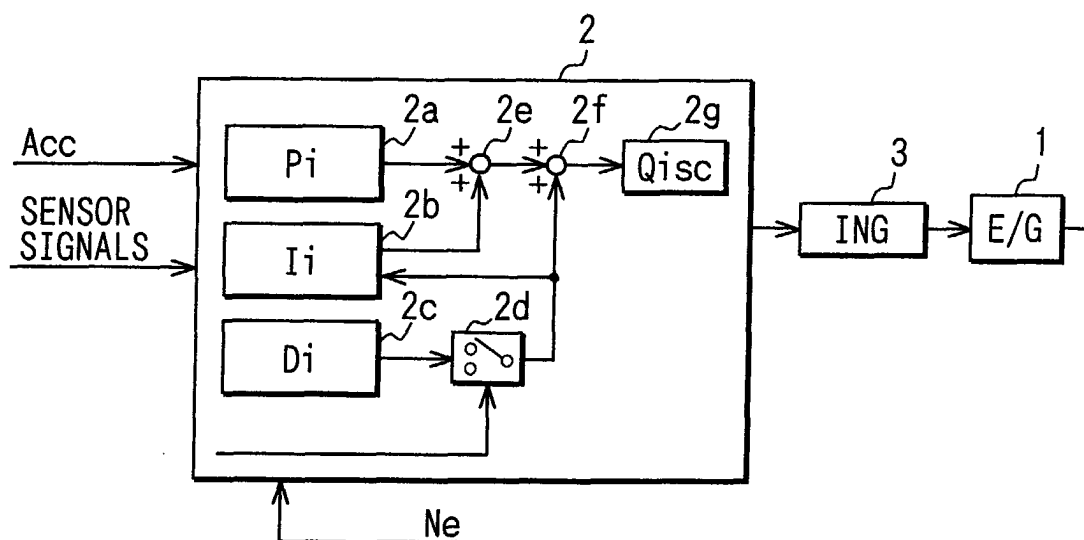
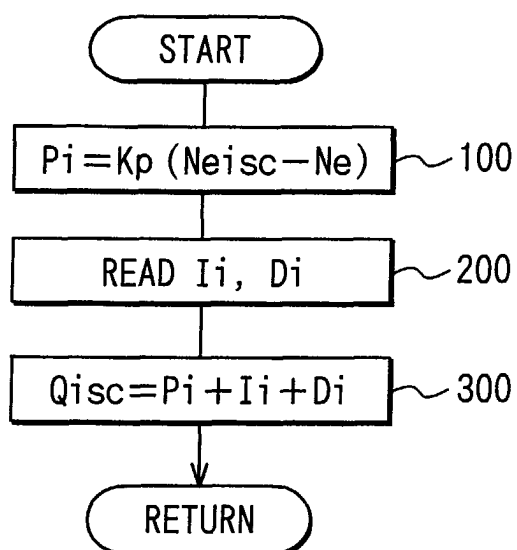
FIG. 1**FIG. 2**

FIG. 3

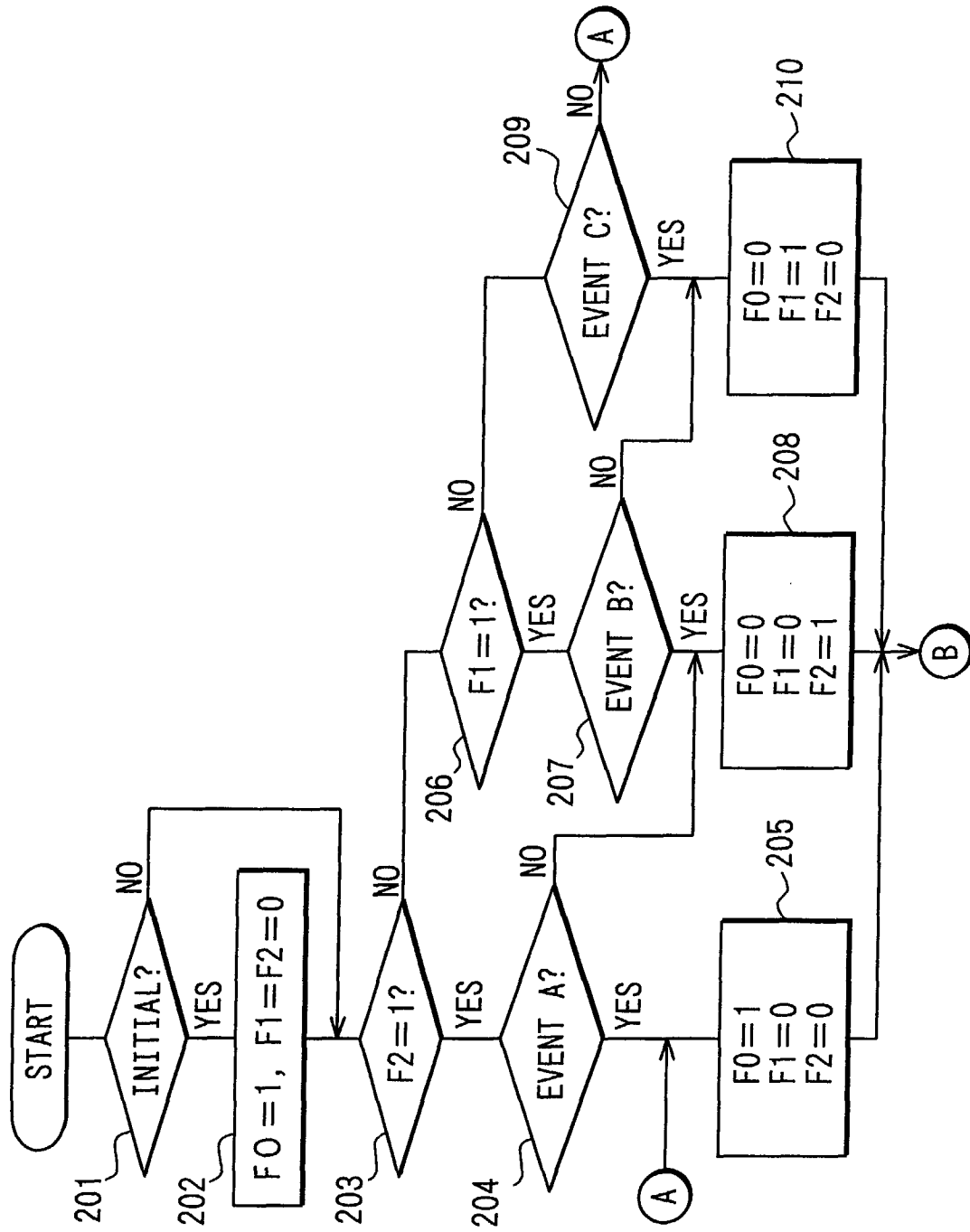


FIG. 4

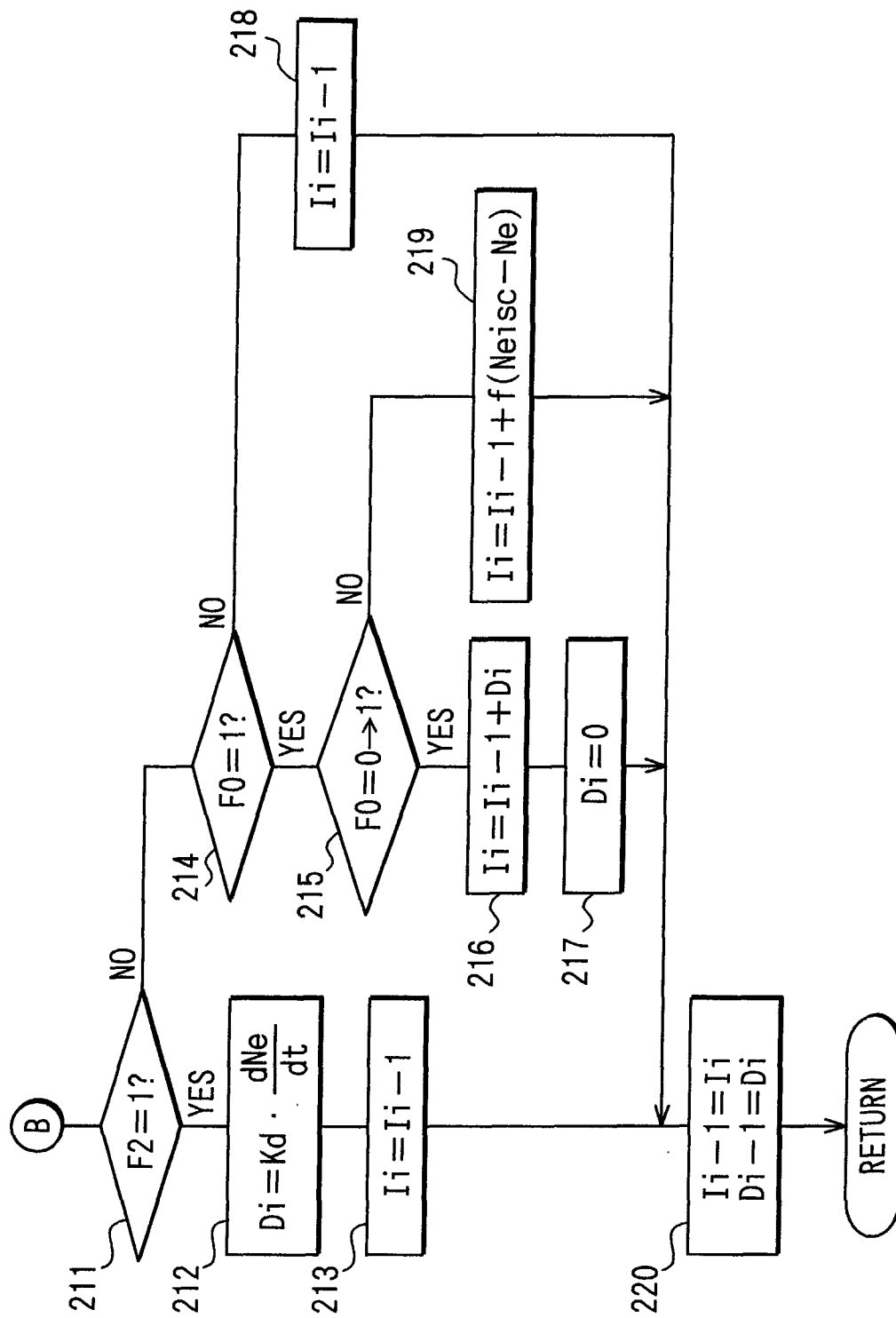


FIG. 5

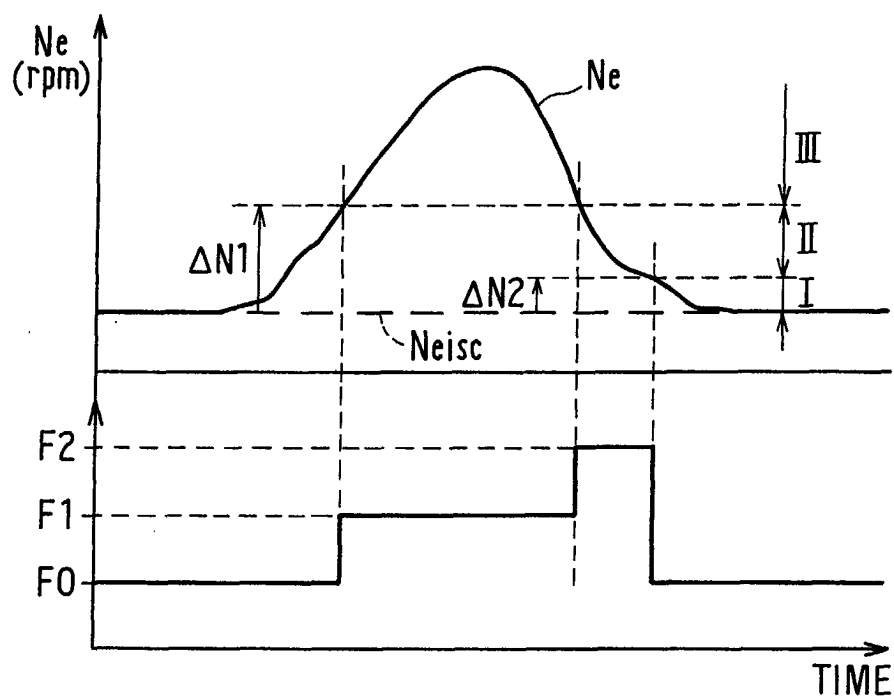


FIG. 6

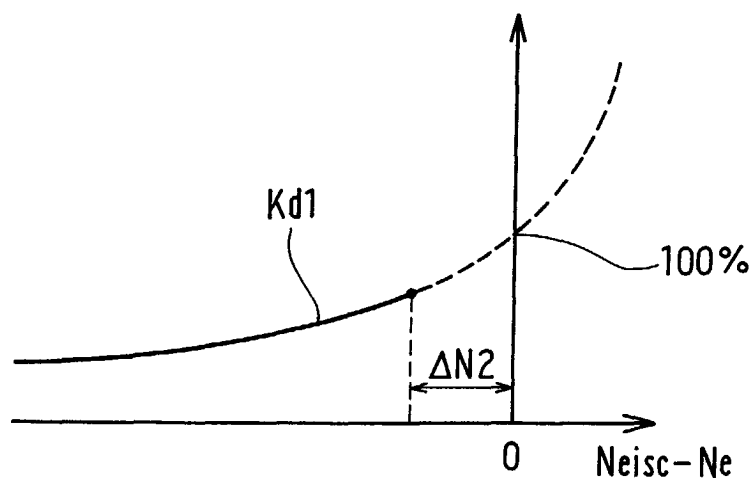


FIG. 7

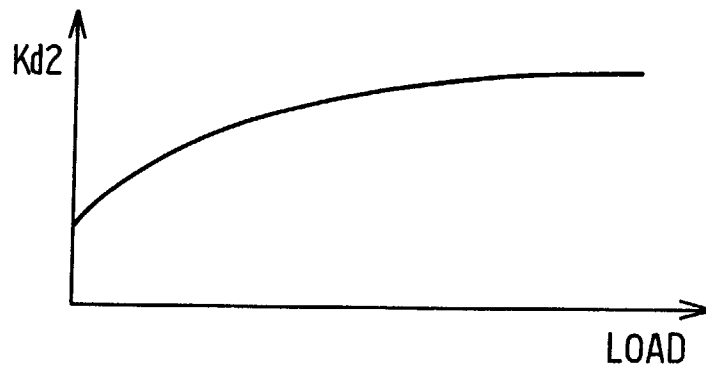


FIG. 8

