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(72) Inventor: **AOYAGI, Shinsuke**
Toyota-shi, Aichi-ken 471-8571 (JP)

(71) Applicant: **TOYOTA JIDOSHA KABUSHIKI
KAISHA**
Toyota-shi, Aichi-ken, 471-8571 (JP)

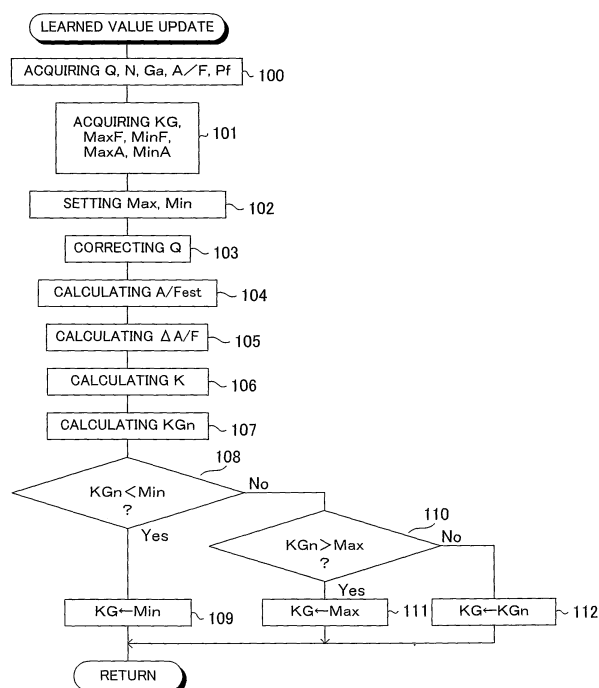
(74) Representative: **Smith, Samuel Leonard**
J A Kemp
14 South Square
Gray's Inn
London WC1R 5JJ (GB)

(54) **APPARATUS FOR CONTROLLING INTERNAL COMBUSTION ENGINE**

(57) This invention relates to a control device of an engine comprising fuel supply means (21) and air supply means (30), for controlling the air-fuel ratio by controlling supplied fuel and air amounts. In this invention, a learned value (KG) used for setting supplied fuel and air amount correction values is calculated such that a difference (Δ

A/F) of the actual air-fuel ratio relative to a target ratio (A/Fest) becomes small. The supplied fuel and air amount correction values are set by using the learned value. The learned value is calculated immediately before the setting of the supplied fuel or air amount correction value and this correction value is set by using the calculated learned value.

FIG.8



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Description

[Technical Field]

[0001] The invention relates to a control device of an internal combustion engine.

[Background Art]

[0002] An air-fuel ratio control device of an internal combustion engine is disclosed in the Patent Document 1. This device controls an air-fuel ratio of a mixture gas of an air and a fuel formed in a combustion chamber of the engine. In particular, the engine of the Document 1 has an intake air amount sensor (i.e. an air flow meter) for detecting an amount of an air flowing through an intake pipe and a fuel injector (i.e. a fuel injection valve) for injecting a fuel into an intake port. The device of the Document 1 calculates an amount of the fuel to be injected from the injector to accomplish a target air-fuel ratio (i.e. an air-fuel ratio of the mixture gas to be targeted) by using the intake air amount (i.e. the amount of the air suctioned into the combustion chamber of the engine) detected by the intake air amount sensor. The target air-fuel ratio can be accomplished by injecting the thus-calculated target fuel injection amount of the fuel from the injector.

[0003] If the intake air amount detected by the intake air amount sensor (hereinafter, this amount will be referred to as --detected intake air amount--) is different from the actual intake air amount, the target fuel injection amount calculated by using the detected intake air amount becomes different from the fuel injection amount which can accomplish the target air-fuel ratio. In this case, when the fuel of the calculated target fuel injection amount is injected from the injector, the target air-fuel amount is not accomplished. In addition, even when a command value for making the injector inject the fuel of the target fuel injection amount is given to the injector, if the amount of the fuel actually injected from the injector is different from the target fuel injection amount, the target air-fuel injection amount is not accomplished.

[0004] That is, in the case that an intake air amount difference in which the detected intake air amount is different from the actual amount occurs or a fuel injection amount difference in which the actual fuel injection amount is different from the target amount occurs, the target air-fuel ratio is not accomplished. Therefore, the device of the Document 1 accomplishes the target air-fuel ratio by the followings even when the intake air or fuel injection amount difference occurs.

[0005] That is, the engine of the Document 1 has in the exhaust pipe an oxygen sensor for detecting an oxygen concentration in the exhaust gas discharged from the combustion chamber (i.e. an oxygen concentration sensor). In the device of the Document 1, the air-fuel ratio of the mixture gas is calculated by using the oxygen concentration detected by this oxygen sensor and then, a difference between this calculated ratio and the target

ratio (hereinafter, this difference will be referred to as-- air-fuel ratio difference--) is calculated. When the engine operation condition (i.e. the operation condition of the engine) is under the condition where the engine speed (i.e. the rotation speed of the engine) is relatively large and the engine load (i.e. the load of the engine) is relatively large, a correction value for correcting the detected intake air amount (hereinafter, this value will be referred to as-- detected intake air amount correction value--) so as to make the calculated air-fuel ratio difference zero or reduce the same is calculated and then, is memorized as a new detected intake air amount correction value. That is, the already memorized detected intake air amount correction value is updated. On the other hand, when the engine operation condition is under the condition where the engine speed is relatively small or the engine load is relatively small, a correction value for correcting the target fuel injection amount (hereinafter, this value will be referred to as-- target fuel injection amount correction value--) so as to make the calculated air-fuel ratio difference zero or reduce the same is calculated and then, is memorized as a new target fuel injection amount correction value. That is, the already memorized target fuel injection amount correction value is updated.

[0006] When the target fuel injection amount is calculated by using the detected intake air amount, this target amount is calculated by using the detected intake air amount corrected by the detected intake air amount correction value, this calculated target amount is corrected by the target fuel injection amount correction value and then, this corrected target amount is set as the final target fuel injection amount. Accordingly, the device of the Document 1 accomplishes the target air-fuel ratio even in the case that the intake air or fuel injection amount difference occurs.

[Prior Technical Document]

[Patent Document]

[0007]

[Patent Document 1] Unexamined JP Patent Publication No. H2-191850

[Patent Document 2] Unexamined JP Patent Publication No. 2005-23937

[Summary of the Invention]

[Problem to be Solved by the Invention]

[0008] As explained above, in the device of the Document 1, when the engine operation condition is under the condition where the engine speed is relatively large and the engine load is relatively large, only the detected intake air amount correction value is updated and on the other hand, when the engine condition is under the other condition, only the target fuel injection amount correction val-

ue is updated. In the device of the Document 1, in order to determine the final target fuel injection amount, both of the detected intake air amount correction value and target fuel injection amount correction value are used. Therefore, when the detected intake air amount correction value is used in order to determine the final target fuel injection amount, this correction value may not be the latest one, depending on the engine operation condition and similarly, when the target fuel injection amount correction value is used in order to determine the final target fuel injection amount, this correction value may not be the latest one, depending on the engine operation condition. That is, when the detected intake air amount and target fuel injection amount correction values are used in order to determine the final fuel injection amount, one of these values may not be the latest one.

[0009] Naturally, while the latest detected intake air amount correction value should be used for the determination of the final target fuel injection amount in order to control the air- fuel ratio to the target ratio accurately, if the detected intake air amount correction value is not the latest one, the air- fuel ratio is not controlled accurately to the target ratio and similarly, while the latest target intake air amount correction value should be used for the determination of the target fuel injection amount in order to control the air- fuel ratio to the target ratio accurately, if the target fuel injection amount correction value is not the latest one, the air- fuel ratio is not controlled accurately to the target ratio.

[0010] The object of the invention is to control the air-fuel ratio to the target ratio by using the correction value relating to the intake air amount or the fuel injection amount.

[Means for Solving the Problem]

[0011] The invention of this application relates to a control device of an internal combustion engine comprising: fuel supply means for supplying a fuel to a combustion chamber and means for supplying an air to the combustion chamber, wherein the device controlling a supplied fuel amount which is an amount of the fuel supplied to the combustion chamber and a supplied air amount which is an amount of the air supplied to the combustion chamber to control an air-fuel ratio of a mixture gas of the air and the fuel formed in the combustion chamber.

[0012] In addition, in this invention, the device calculates a learned value used for setting a supplied fuel amount correction value for correcting the supplied fuel amount or a supplied air amount correction value for correcting the supplied air amount as a value which decreases the difference of the air-fuel ratio on the basis of a difference of an actual air-fuel ratio relative to a target air-fuel ratio and the device sets the supplied fuel or air amount correction value by using the learned value.

[0013] In addition, in this invention, the device calculates the learned value immediately before the setting of

the supplied fuel or air amount correction value and sets the supplied fuel or air amount correction value by using this calculated learned value.

[0014] According to this, the supplied fuel or air amount correction value is set and thereafter, the learned value is newly calculated before the supplied fuel or air amount is corrected by the set supplied fuel or air amount correction value. That is, the learned value is updated as the latest learned value. This learned value is used for setting the supplied fuel or air amount correction value. Therefore, the latest learned value is used for the setting of the supplied fuel or air amount correction value. Further, immediately before the setting of the supplied fuel or air amount correction value, the latest learned value is calculated and therefore, the current optimum learned value is used for the setting of the supplied fuel or air amount correction value. Thus, the inappropriate correction of the supplied fuel or air amount is avoided and therefore, the air-fuel ratio is accurately controlled to the target air-fuel ratio.

[0015] In the above-explained invention, in the case that the supplied fuel amount correction value is set by using the learned value, it is preferred that the performance of the calculation of the learned value is activated by the determination of the performance of the setting of the supplied fuel amount correction value and the setting of the supplied fuel amount correction value is performed according to the determination after the calculation of the learned value is completed. Further, in the above-explained invention, in the case that the supplied air amount correction value is set by using the learned value, it is preferred that the performance of the calculation of the learned value is activated by the determination of the performance of the setting of the supplied air amount correction value and the setting of the supplied air amount correction value is performed according to the determination after the calculation of the learned value is completed.

[0016] Further, in the above- explained invention, it is preferred that the calculation of the learned value is performed every a predetermined time has elapsed.

[0017] In addition, in the case that the supplied fuel amount correction value is set by using the learned value, the setting of the supplied fuel amount correction value is performed every a predetermined time has elapsed. In this case, the timing of performing the setting of the supplied fuel amount correction value and the timing of performing the calculation of the learned value are set such that the time period between the timing of performing the setting of the supplied fuel amount correction value and the timing of performing the calculation of the learned value immediately therebefore is shorter than that between the timing of performing the setting of the supplied fuel amount correction value and the timing of performing the calculation of the learned value immediately thereafter.

[0018] Further, in the case that the supplied air amount correction value is set by using the learned value, the

setting of the supplied air amount correction value is performed every a predetermined time has elapsed. In this case, the timing of performing the setting of the supplied air amount correction value and the timing of performing the calculation of the learned value are set such that the time period between the timing of performing the setting of the supplied air amount correction value and the timing of performing the calculation of the learned value immediately thereafter is shorter than that between the timing of performing the setting of the supplied air amount correction value and the timing of performing the calculation of the learned value immediately thereafter.

[0019] Further, in the above- explained invention, it is preferred that an upper limit value or a lower limit value regarding the learned value is set. In this case, when the calculated learned value is larger than the upper limit value, the upper limit value is set as the learned value and when the calculated learned value is smaller than the lower limit value, the lower limit value is set as the learned value. In this regards, the learned value is set as the upper or lower limit value, which learned value being estimated to be calculated when the supplied fuel amount difference amount, which is a difference amount of the actual supplied fuel amount relative to the estimated supplied fuel amount which is an estimated value of the supplied fuel amount, is a predetermined amount.

[0020] According to this, in the case that the upper or lower limit value regarding the learned value has been set, before the learned value calculated immediately before the setting of the supplied fuel or air amount correction value is used for the setting, when the learned value is larger than the upper limit value, the learned value is limited to the upper limit value or when the learned value is smaller than the lower limit value, the learned value is limited to the lower limit value. Thus, the use of the learned value larger than the upper limit value or smaller than the lower limit value for the setting of the supplied fuel or air amount correction value is avoided.

[0021] Further, in the above- explained invention, it is preferred that the predetermined supplied fuel amount difference amount is determined on the basis of at least one of the supplied fuel amount and the pressure of the fuel supplied from the fuel supply means.

[0022] According to this, the more suitable upper or lower limit value is set for limiting the learned value such that the requirements of the engine (for example, the decrease of the exhaust emission, the improvement of the fuel consumption, the avoidance of the misfiring in the combustion chamber, etc.) are surely accomplished. That is, the supplied fuel amount difference is significantly subject to the supplied fuel amount and the fuel pressure when the fuel is supplied from the fuel supply means. Further, the above-mentioned predetermined supplied fuel amount difference amount is used for the setting of the upper or lower limit value. On the other hand, the supplied fuel amount difference significantly influences the requirements of the engine. Therefore, if the above-mentioned predetermined supplied fuel amount difference

amount is determined on the basis of at least one of the supplied fuel amount and the fuel pressure, the more suitable upper or lower limit value is set for limiting the learned value such that the requirements of the engine are surely accomplished.

[0023] Further, in the above- explained invention, it is preferred that the predetermined supplied fuel amount difference amount is the maximum or minimum value among the possible supplied fuel amount difference amounts.

[0024] According to this, the more suitable upper or lower limit value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished. That is, in general, it is preferred that the supplied fuel or air amount is corrected to the maximum extent possible as far as the requirements of the engine are accomplished. On the other hand, also in the case that it is expected that the supplied fuel amount difference amount becomes large to the maximum extent when the actual supplied fuel amount differs positively from the estimated supplied fuel amount (i.e. in the case that the supplied fuel amount difference amount is the possible maximum value) and in the case that it is expected that the supplied fuel amount difference amount becomes large to the maximum extent when the actual supplied fuel amount differs negatively from the estimated supplied fuel amount (i.e. in the case that the supplied fuel amount difference amount is the possible minimum value), a variety of the controls in the engine are constructed such that the requirements of the engine are accomplished. That is, if the learned value is limited to the upper or lower limit value set by using the maximum or minimum value among the expected supplied fuel amount difference amounts as the above-mentioned supplied fuel amount difference amount, the learned value for correcting the supplied fuel or air amount to the maximum extent and accomplishing the requirements of the engine is obtained. Therefore, the more suitable upper or lower limit value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished.

[0025] Further, in the above- explained invention, it is preferred that the upper or lower limit value regarding the learned value is set. In this case, when the calculated learned value is larger than the upper limit value, the learned value is limited to the upper limit value or when the calculated learned value is smaller than the lower limit value, the learned value is limited to the lower limit value. In this regards, the learned value is set as the upper or lower limit value, which learned value is expected to be calculated when the supplied air amount difference amount which is a difference amount of the estimated supplied air amount which is an estimated value of the supplied air amount relative to the actual supplied air amount is a predetermined supplied air amount.

[0026] According to this, in the case that the upper or lower limit value regarding the learned value is set, before

the learned value calculated immediately before the setting of the supplied fuel or air amount correction value is used for the setting, when the learned value is larger than the upper limit value, the learned value is limited to the upper limit value or when the learned value is smaller than the lower limit value, the learned value is limited to the lower limit value. Thus, the use of the learned value larger than the upper limit value or smaller than the lower limit value for the setting of the supplied fuel or air amount correction value is avoided.

[0027] Further, in the above- explained invention, it is preferred that the predetermined supplied air amount difference amount is determined on the basis of the supplied air amount.

[0028] According to this, the more suitable upper or lower limit value is set in order to limit the learned value such that the requirements of the engine are surely accomplished. That is, the supplied air amount difference is significantly subject to the supplied air amount. The predetermined supplied air amount difference amount is used for the setting of the upper or lower limit value. On the other hand, the supplied air amount difference influences the requirements of the engine. Therefore, if the predetermined supplied air amount difference amount is determined on the basis of the supplied air amount, the more suitable upper or lower limit value is set in order to limit the learned value such that the requirements of the engine are surely accomplished.

[0029] Further, in the above- explained invention, it is preferred that the predetermined supplied air amount difference amount is the maximum or minimum value among the possible supplied air amount difference amounts.

[0030] According to this, the more suitable upper or lower limit value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished. That is, in general, it is preferred that the supplied fuel or air amount is corrected to the maximum extent possible as far as the requirements of the engine are accomplished. On the other hand, a variety of the controls in the engine are constructed such that the requirements of the engine are accomplished in the case that it is expected that the supplied air amount difference amount becomes large to the maximum extent when the estimated supplied air amount differs positively from the actual supplied air amount (i.e. in the case that the supplied air amount difference amount is the possible maximum value) and in the case that it is expected that the supplied air amount difference amount becomes large to the maximum extent when the estimated supplied air amount differs negatively from the actual supplied air amount (i.e. in the case that the supplied air amount difference amount is the possible minimum value). That is, when the learned value is limited to the upper or lower limit value set by using the maximum or minimum value of the possible supplied air amount difference amount as the above-mentioned predetermined supplied air amount dif-

ference amount, the learned value is obtained, which value corrects the supplied fuel or air amount to the maximum extent while the requirements of the engine are accomplished. Therefore, the more suitable upper or lower limit value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished.

[0031] Further, in the above- explained invention, it is preferred that the supplied fuel amount correction value is a value for decreasing the difference of the actual supplied fuel amount relative to the estimated supplied fuel amount which is an estimated value of the supplied fuel amount.

[0032] Further, in the above- explained invention, it is preferred that the supplied air amount correction value is a value for decreasing the difference of the estimated supplied air amount, which is an estimated value of the supplied air amount, relative to the actual supplied air amount.

[0033] Further, another invention of this application relates to a control device of an internal combustion engine, comprising

means for acquiring an estimated value of a supplied fuel amount, which is an amount of a fuel supplied to a combustion chamber, as an estimated supplied fuel amount, means for acquiring an estimated value of a supplied air amount, which is an amount of an air supplied to the combustion chamber, as an estimated supplied air amount,

means for calculating an air- fuel ratio of a mixture gas formed in the combustion chamber as an estimated air- fuel ratio on the basis of the estimated supplied fuel and air amounts,

means for acquiring an actual air- fuel ratio of the mixture gas formed in the combustion chamber as an actual air- fuel ratio,

correction value calculation means for calculating a correction value for correcting the supplied air amount so as to decrease an air- fuel ratio difference which is a difference of the actual air- fuel ratio relative to the estimated air- fuel ratio, and

learning means for calculating a learned value of the correction value by integrating the correction values calculated by the correction value calculation means and memorizing the learned value,

wherein when no air- fuel ratio difference occurs, the supplied air amount is corrected only by the learned value, and on the other hand, when the air- fuel ratio difference occurs, the supplied air amount is corrected by the learned value and the correction value.

[0034] In this invention, the learned value is obtained as a maximum lean-side learned value due to the supplied fuel amount difference, which learned value is obtained when the air-fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is larger than the estimated supplied air amount occurs and this supplied fuel amount difference is largest among the possible differ-

ences under the condition where the estimated supplied air amount corresponds to the actual supplied air amount.

[0035] Further, in this invention, the learned value is obtained as a maximum rich- side learned value due to the supplied fuel amount difference, which learned value is obtained when the air- fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs and this supplied fuel amount is largest among the possible differences under the condition where the estimated supplied air amount corresponds to the actual supplied air amount.

[0036] Further, in this invention, the learned value is obtained as a maximum lean- side learned value due to the supplied air amount difference, which learned value is obtained when the air- fuel ratio difference becomes zero in the case that a supplied air amount difference in which the estimated supplied air amount is larger than the actual supplied air amount occurs and this supplied air amount difference is largest among the possible differences under the condition where the estimated supplied fuel amount corresponds to the actual supplied fuel amount.

[0037] Further, in this invention, the learned value is obtained as a maximum rich- side learned value due to the supplied air amount difference, which learned value is obtained when the air- fuel ratio difference becomes zero in the case that a supplied air amount difference in which the estimated supplied air amount is smaller than the actual supplied air amount occurs and this supplied air amount difference is largest among the possible differences under the condition where the estimated supplied fuel amount corresponds to the actual supplied fuel amount.

[0038] Further, in this invention, the larger one of the maximum lean- side learned values due to the supplied fuel and air amount differences is set as an upper limit lean- side learned value.

[0039] Further, in this invention, the larger one of the maximum rich- side learned values due to the supplied fuel and air amount differences is set as an upper limit rich- side learned value.

[0040] Further, in this invention, the learned value is limited to the upper limit lean- side learned value when the learned value calculated by the learning means is a value for increasing the supplied air amount and is larger than the upper limit lean- side learned value.

[0041] On the other hand, in this invention, the learned value is limited to the upper rich-side learned value when the learned value calculated by the learning means is a value for decreasing the supplied air amount and is larger than the upper limit rich-side learned value.

[0042] According to this, the more suitable upper limit lean-side or rich-side learned value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished. That is, in general, it is preferred that the supplied fuel or air amount is corrected to the maximum

extent possible as far as the requirements of the engine are accomplished. On the other hand, a variety of the controls in the engine are structured such that the requirements of the engine are accomplished in the case that it is expected that the supplied fuel amount difference amount becomes large to the maximum extent when the actual supplied fuel amount differs positively from the estimated supplied fuel amount and in the case that it is expected that the supplied fuel amount difference amount becomes large to the maximum extent when the actual supplied fuel amount differs negatively from the estimated supplied fuel amount. That is, when the learned value in the case that the supplied fuel amount difference is largest among the possible differences (i.e. the maximum lean-side and rich-side learned values due to the supplied fuel amount difference) and the learned value in the case that the supplied air amount difference is largest among the possible differences (i.e. the maximum lean-side and rich-side learned values due to the supplied air amount difference) are compared with each other, the larger one of these learned values is set as the upper limit lean-side or rich-side learned value, and the learned value is limited to the upper limit lean-side or rich-side learned value, the learned value is obtained, which learned value corrects the supplied fuel or air amount to the maximum extent while the requirements of the engine are accomplished. Therefore, the more suitable upper limit lean-side or rich-side learned value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished.

[0043] In the above-explained invention, it is preferred that the maximum lean-side and rich-side learned values due to the supplied fuel amount difference are ones defined by at least one of the estimated supplied fuel amount and the pressure of a fuel supplied from fuel supply means.

[0044] According to this, the more suitable upper limit lean-side or rich-side learned value is set in order to limit the learned value such that the requirements of the engine are accomplished. That is, the supplied fuel amount difference is subject to the supplied fuel amount and the pressure of a fuel supplied from fuel supply means. The maximum lean-side and rich-side learned values due to the supplied fuel amount difference are used for the setting of the upper limit lean-side and rich-side learned values, respectively. On the other hand, the supplied fuel amount difference influences the requirements of the engine. Therefore, when the maximum lean-side and rich-side learned values due to the supplied fuel amount difference are defined on the basis of at least one of the supplied fuel amount and the above-mentioned fuel pressure, the more suitable upper limit lean-side or rich-side learned value is set in order to limit the learned value such that the requirements of the engine are surely accomplished.

[0045] Further, in the above- explained invention, it is preferred that the maximum rich- side and lean- side

learned values due to the supplied air amount difference are defined by the estimated supplied air amount.

[0046] According to this, the more suitable upper limit lean-side or rich-side learned value is set in order to limit the learned value such that the requirements of the engine are surely accomplished. That is, the supplied air amount difference is subject to the intake air amount. The maximum lean-side and rich-side learned values due to the supplied air amount difference are used for the setting of the upper limit lean-side and rich-side learned values, respectively. On the other hand, the supplied air amount influences the requirements of the engine. Therefore, when the maximum lean-side and rich-side learned values due to the supplied air amount are defined on the basis of the supplied air amount, the more suitable upper limit lean-side or rich-side learned value is set in order to limit the learned value such that the requirements of the engine are surely accomplished.

[0047] Further another invention of this application relates to a control device of an internal combustion engine, comprising

means for acquiring an estimated value of a supplied fuel amount, which is an amount of a fuel supplied to a combustion chamber, as an estimated supplied fuel amount, means for acquiring an estimated value of a supplied air amount, which is an amount of an air supplied to the combustion chamber, as an estimated supplied air amount,

means for calculating an air-fuel ratio of a mixture gas formed in the combustion chamber as an estimated air-fuel ratio on the basis of the estimated supplied fuel and air amounts,

means for acquiring an actual air-fuel ratio of the mixture gas formed in the combustion chamber as an actual air-fuel ratio,

correction value calculation means for calculating a correction value for correcting the supplied air amount so as to decrease an air-fuel ratio difference which is a difference of the actual air-fuel ratio relative to the estimated air-fuel ratio, and

learning means for calculating a learned value of the correction value by integrating the correction value calculated by the correction value calculation means and memorizing the learned value,

wherein when no air-fuel ratio difference occurs, the supplied air amount is corrected only by the learned value, and on the other hand, when the air-fuel ratio difference occurs, the supplied air amount is corrected by the learned value and the correction value.

[0048] Further, in this invention, the learned value is set to an upper limit lean-side learned value, which learned value is obtained when the air-fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is larger than the estimated supplied fuel amount occurs, this supplied fuel amount difference is largest among the possible differences, a supplied air amount difference in which the estimated supplied air amount is

larger than the actual supplied air amount, and this supplied air amount difference is largest among the possible differences.

[0049] Further, in this invention, the learned value is set to an upper limit rich-side learned value, which learned value is obtained when the air-fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs, this difference is largest among the possible differences, a supplied air amount difference in which the estimated supplied air amount is smaller than the actual supplied air amount occurs, and this difference is largest among the possible differences.

[0050] Further, in this invention, when the learned value calculated by the learning means is a value for increasing the supplied air amount and is larger than the upper limit lean-side learned value, the learned value is limited to the upper limit lean-side learned value.

[0051] On the other hand, in this invention, when the learned value calculated by the learning means is a value for decreasing the supplied air amount and is larger than the upper limit rich-side learned value, the learned value is limited to this upper limit value.

[0052] According to this, the suitable upper lean-side and rich-side learned values are set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished. That is, in general, it is preferred that the supplied fuel or air amount is corrected to the maximum extent possible as far as the requirements of the engine are accomplished. On the other hand, the various controls of the engine are structured such that the requirements of the engine are accomplished in the case of expecting that the supplied fuel amount difference amount is the largest one when the actual supplied fuel amount is different from the estimated supplied fuel amount positively and the supplied air amount difference amount is the largest one when the estimated supplied air amount is different from the actual supplied air amount positively and in the case of expecting that the supplied fuel amount difference amount is the largest one when the actual supplied fuel amount is different from the estimated supplied fuel amount negatively and the supplied air amount difference amount is the largest one when the estimated supplied air amount is different from the actual supplied air amount negatively. That is, the learned value in the case that the supplied fuel and air amount difference are the largest ones to the expected extent are set to the upper limit lean-side or rich-side learned value and when the learned value is limited to the upper limit value, the learned value for correcting the supplied fuel or air amount to the maximum extent while the requirements of the engine are accomplished can be obtained. Therefore, the more suitable upper limit lean-side or rich-side learned value is set in order to correct the supplied fuel or air amount to the maximum extent possible as far as the requirements of the engine are accomplished.

[0053] In the above-explained invention, it is preferred that the upper limit rich-side and lean-side learned values are those defined by at least one of the estimated supplied fuel amount and the fuel pressure when the fuel is supplied from the fuel supply means.

[0054] According to this, the more suitable upper limit lean-side or rich-side learned value is set in order to limit the learned value so as to surely accomplish the requirements of the engine. That is, the supplied fuel amount difference is subject to the supplied fuel amount and the pressure of a fuel supplied from fuel supply means. The supplied air amount difference is subject to the intake air amount. The supplied fuel and air amounts influence the requirements of the engine. Therefore, when the upper limit lean-side and rich-side learned values are defined on the basis of the estimated supplied air amount and at least one of the supplied fuel amount and the fuel pressure, the more suitable upper limit lean-side or rich-side learned value for limiting the learned value so as to surely accomplish the requirements of the engine is set.

[0055] In the above-explained invention, it is preferred that the device further comprises exhaust gas recirculation means for introducing into an intake passage an exhaust gas discharged from the combustion chamber to an exhaust passage. The correction value calculated by the correction value calculation means is the correction value for correcting an exhaust gas recirculation amount which is an amount of the exhaust gas introduced into the intake passage by the exhaust gas recirculation means.

[Brief Explanation of the Drawings]

[0056]

[Fig. 1] Fig. 1 is an entire view showing an internal combustion engine which a control device of the first embodiment of the invention is applied.

[Fig. 2] Fig. 2(A) is a view showing a map used for acquiring a target fuel injection amount on the basis of an accelerator pedal opening degree D_{ac} in the first embodiment, Fig. 2(B) is a view showing a map used for acquiring a target throttle valve opening degree TD_{th} on the basis of a fuel injection amount Q and an engine speed N in the first embodiment and Fig. 2(C) is a view showing a map used for acquiring a target EGR rate TR_{egr} on the basis of the fuel injection amount Q and the engine speed in the first embodiment.

[Fig. 3] Fig. 3 is a view showing a map used for acquiring a learned value KG on the basis of the fuel injection amount TQ and the engine speed N in the first embodiment.

[Fig. 4] Fig. 4(A) is a view showing a map used for acquiring a maximum learned value $MaxF$ due to a fuel injection amount difference on the basis of the fuel injection amount Q and a fuel pressure P_f in the first embodiment, Fig. 4(B) is a view showing a map

used for acquiring a minimum learned value $MinF$ due to the fuel injection amount difference on the basis of the fuel injection amount Q and the fuel pressure P_f in the first embodiment,

Fig. 4(C) is a view showing a map used for acquiring a maximum learned value $MaxA$ due to an intake air amount difference on the basis of an intake air amount G_a in the first embodiment and Fig. 4(D) is a view showing a map used for acquiring a minimum learned value $MinA$ due to the intake air amount difference on the basis of the intake air amount G_a in the first embodiment.

[Fig. 5] Fig. 5 shows a flowchart of a routine for performing a control of a fuel injector of the first embodiment.

[Fig. 6] Fig. 6 shows a flowchart of a routine for performing a control of a throttle valve of the first embodiment.

[Fig. 7] Fig. 7 shows a flowchart of a routine for performing a control of an EGR control valve of the first embodiment.

[Fig. 8] Fig. 8 shows a flowchart of a routine for performing an update of the learned value of the first embodiment.

[Fig. 9] Fig. 9 is a view showing a map used for acquiring a maximum learned value Max on the basis of the fuel injection amount Q and the fuel pressure P_f in the second embodiment and Fig. 9(B) is a view for a map used for acquiring a minimum learned value Min on the basis of the fuel injection amount Q , the fuel pressure P_f and the intake air amount G_a in the second embodiment.

[Fig. 10] Fig. 10 shows a flowchart of a routine for performing the update of the learned value of the second embodiment.

[Fig. 11] Fig. 11 is an entire view of the engine which the control device of the third embodiment of this invention is applied.

[Fig. 12] Fig. 12(A) is a view showing a map used for acquiring the target fuel injection amount TQ on the basis of the accelerator pedal opening degree D_{ac} in the third embodiment and Fig. 12(B) is a view showing a map used for acquiring the target throttle valve opening degree TD_{th} on the basis of the fuel injection amount Q and the engine speed N in the third embodiment.

[Fig. 13] Fig. 13 is a view showing a map used for acquiring the learned value KG on the basis of the fuel injection amount Q and the engine speed N in the third embodiment.

[Fig. 14] Fig. 14 shows a flowchart of a routine for performing the control of the throttle valve in the third embodiment.

[Fig. 15] Fig. 15 is an entire view of the engine which the control device of the second embodiment of this invention is applied.

[Fig. 16] Fig. 16 is a view showing an exhaust turbine of a supercharger of the engine shown in Fig. 15.

[Fig.17] Fig.17(A) is a view showing a map used for acquiring the target fuel injection amount TQ on the basis of the accelerator pedal opening degree Dac in the fourth embodiment, Fig.17(B) is a view showing a map used for acquiring the target throttle valve opening degree TDth on the basis of the fuel injection amount Q and the engine speed N in the fourth embodiment, and Fig.17(C) is a view showing a map used for acquiring the target vane opening degree TDv on the basis of the fuel injection amount Q and the engine speed N in the fourth embodiment.

[Fig.18] Fig.18 is a view showing a map used for acquiring the learned value KG on the basis of the fuel injection amount Q and the engine speed N in the fourth embodiment.

[Fig.19] Fig.19 shows a flowchart of a routine for performing the control of the vane of the fourth embodiment.

[Fig.20] Fig.20 is a view showing a map used for acquiring the learned value KG on the basis of the fuel injection amount Q and the engine speed N in the fifth embodiment.

[Fig.21] Fig.21 shows a flowchart of a routine for performing the control of the fuel injector of the fifth embodiment.

[Fig.22] Fig.22 shows a flowchart of a routine for performing the control of the EGR control valve of the fifth embodiment.

[Fig.23] Fig.23 is a view showing a map used for acquiring the learned value KG on the basis of the fuel injection amount Q and the engine speed N in the sixth embodiment.

[Mode for Carrying Out the Invention]

[0057] Below, embodiments of the control device of the internal combustion engine of this invention will be explained, referring to the drawings. An internal combustion engine which a control device of the first embodiment is applied is shown in Fig. 1. The engine 10 of Fig. 1 comprises a body 20 of the engine (hereinafter, this body will be referred to as -- engine body--), fuel injectors 21 each positioned to corresponding one of four combustion chambers of the body and a fuel pump 22 for supplying a fuel to the injectors 21 via a fuel supply pipe 23. The engine 10 comprises an intake system 30 for supplying an air to the combustion chambers from the atmosphere and an exhaust system 40 for discharging an exhaust gas discharged from the combustion chamber to the atmosphere. The engine 10 is a compression self ignition type internal combustion engine (a so-called diesel engine).

[0058] The intake system 30 has an intake manifold 31 and an intake pipe 32. In the following explanation, the intake system 30 may be referred to as --intake passage--. One end of the intake manifold 31 (i.e. the branch portions) is connected to intake ports (not shown) formed in the body 20 corresponding to each combustion cham-

ber. The other end of the intake manifold 31 is connected to the intake pipe 32. A throttle valve 33 for controlling an amount of an air flowing through the intake pipe is positioned in the intake pipe 32. An intercooler 34 for cooling the air flowing through the intake pipe is positioned on the intake pipe 32. An air cleaner 36 is positioned in the end of the intake pipe 32 facing the atmosphere.

[0059] The throttle valve 33 can variably control an amount of a gas suctioned into the combustion chambers by its operation condition (in particular, its opening degree and hereinafter, this degree will be referred to as --throttle valve opening degree--) being controlled.

[0060] The exhaust system 40 has an exhaust manifold 41 and an exhaust pipe 42. In the following explanation, the exhaust system 40 may be referred to as --exhaust passage--. One end of the exhaust manifold 41 (i.e. the branch portions) is connected to exhaust ports (now shown) formed in the body 20 corresponding to each combustion chamber. The other end of the exhaust manifold 41 is connected to the exhaust pipe 42. A catalytic converter 43 incorporating an exhaust purification catalyst 43A for purifying specific components in the exhaust gas is positioned in the exhaust pipe 42.

[0061] An oxygen concentration sensor 76U for outputting a signal depending on an oxygen concentration in the exhaust gas discharged from the combustion chamber (hereinafter, this sensor will be referred to as --upstream oxygen concentration sensor--) is positioned on the exhaust pipe 42 upstream of the catalyst 43A. An oxygen concentration sensor 76D for outputting a signal depending on the oxygen concentration in the exhaust gas discharged from the catalyst 43A (hereinafter, this sensor will be referred to as --downstream oxygen concentration sensor) is positioned on the exhaust pipe 42 downstream of the catalyst 43A.

[0062] An air flow meter 71 for outputting a signal depending on a flow rate of the air flowing through the intake pipe (therefore, the flow rate of the air suctioned into the combustion chamber and hereinafter, this rate will be referred to as --intake air amount--) is positioned on the intake pipe 32 downstream of the air cleaner 36 and upstream of a compressor 35A. A pressure sensor for outputting a signal depending on a pressure of the gas in the intake manifold (i.e. an intake pressure) 72 is positioned on the intake manifold 31. A crank position sensor 74 for outputting a signal depending on a rotation phase of a crank shaft is positioned on the body 20.

[0063] The engine 10 comprises an exhaust gas recirculation device (hereinafter, this will be referred to as --EGR device--) 50. The device 50 has an exhaust gas recirculation pipe (hereinafter, this will be referred to as --EGR passage--) 51. One end of the passage 51 is connected to the exhaust manifold 41. That is, one end of the passage 51 is connected to the portion of the exhaust passage 40 upstream of an exhaust turbine 35B. The other end of the passage 51 is connected to the intake manifold 31. That is, the other end of the passage 51 is

connected to the portion of the intake passage downstream of the compressor 35A. An exhaust gas recirculation control valve (hereinafter, this will be referred to as --EGR control valve) 52 for controlling a flow rate of an exhaust gas flowing through the EGR passage is positioned on the passage 51. In the engine 10, as an opening degree of the valve 52 (hereinafter, this degree will be referred to as --EGR control valve opening degree--) is large, the flow rate of the exhaust gas flowing through the EGR passage 51 is large. An exhaust gas recirculation cooler 53 for cooling the exhaust gas flowing through the EGR passage is positioned in the passage 51.

[0064] The EGR device 50 can variably control the amount of the exhaust gas introduced into the intake passage 30 via the EGR passage 51 (hereinafter, this gas will be referred to as --EGR gas--) by controlling the operation condition of the EGR control valve 52 (in particular, the opening degree of the valve 52 and hereinafter, this will be referred to as EGR control valve opening degree--).

[0065] The engine 10 comprises an electronic control unit 60. The unit 60 has a microprocessor (CPU) 61, a read only memory (ROM) 62, a random access memory (RAM) 63, a back-up RAM 64 and an interface 65. The injectors 21, the pump 22, the throttle valve 33 and the EGR control valve 52 are connected to the interface 65 and the control signals for controlling their operations are given from the unit 60 via the interface 65, respectively. The air flow meter 71, the intake pressure sensor 72, the crank position sensor 74, an accelerator pedal opening degree sensor 75 for outputting a signal depending on an opening degree of an accelerator pedal AP (i.e. the depression amount of the pedal AP and hereinafter, this will be referred to as --accelerator pedal opening degree--) and the oxygen concentration sensors 76U and 76D are connected to the interface 65 and the signals output from the meter 71 and the sensors 72, 74, 75, 76U and 76D are input to the interface 65.

[0066] The intake air amount is calculated by the unit 60 on the basis of the signal output from the air flow meter 71, the intake pressure is calculated by the unit 60 on the basis of the signal output from the intake pressure sensor 72, the engine speed (i.e. the rotation speed of the engine 10) is calculated by the unit 60 on the basis of the signal output from the crank position sensor 74, the accelerator pedal opening degree is calculated by the unit 60 on the basis of the signal output from the accelerator pedal opening degree sensor 75, the air-fuel ratio of the exhaust gas discharged from the combustion chamber is calculated by the unit 60 on the basis of the signal output from the upstream oxygen concentration sensor 76U and the air-fuel ratio of the exhaust gas flowing out from the catalyst 43A is calculated by the unit 60 on the basis of the signal output from the downstream oxygen concentration sensor 76D. Therefore, in the first embodiment, substantially, the air flow meter 71 functions as means for detecting the intake air amount, the intake pressure sensor 72 functions as means for detect-

ing the intake air pressure, the crank position sensor 74 functions as means for detecting the engine speed, the accelerator pedal opening degree sensor 75 functions as means for detecting the accelerator pedal opening degree, the upstream oxygen concentration sensor 76U functions as means for detecting the oxygen concentration of the exhaust gas discharged from the combustion chamber and the downstream oxygen concentration sensor 76D functions as means for detecting the oxygen concentration of the exhaust gas flowing out from the catalyst 43A.

[0067] As the intake pressure is high, the amount of the gas suctioned into the combustion chamber is large and as the intake pressure is low, the amount of the gas is small. The intake pressure sensor 72 functions as means for detecting the intake pressure and therefore, the amount of the gas suctioned into the combustion chamber can be known on the basis of the intake pressure detected by the sensor 72. Therefore, in the first embodiment, substantially, the sensor 72 functions as means for detecting the amount of the gas suctioned into the combustion chamber.

[0068] As the air-fuel ratio of the mixture gas is large, the oxygen concentration of the burned gas produced by the combustion of the mixture gas formed in the combustion chamber is large and as the air-fuel ratio of the mixture gas is small, the oxygen concentration is small. In the case that the oxygen concentration of the burned gas produced by the combustion when the mixture gas having the stoichiometric air-fuel ratio burns in the combustion chamber is referred to as base oxygen concentration, the oxygen concentration of the burned gas produced by the combustion of the mixture gas formed in the combustion chamber is higher than the base oxygen concentration when the air-fuel ratio of the mixture gas is larger than the stoichiometric air-fuel ratio and the oxygen concentration is lower than the base oxygen concentration when the air-fuel ratio of the mixture gas is smaller than the stoichiometric air-fuel ratio. The upstream oxygen concentration sensor 76U functions as means for detecting the oxygen concentration of the exhaust gas discharged from the combustion chamber and therefore, the air-fuel ratio of the mixture gas can be known on the basis of the oxygen concentration detected by the sensor 76U. Therefore, in the first embodiment, substantially, the sensor 76U functions as means for detecting the air-fuel ratio of the mixture gas.

[0069] Next, the control of the fuel injector of the first embodiment will be explained. In the first embodiment, suitable fuel injection amounts (i.e. amounts of the fuel injected from the fuel injector) depending on the accelerator pedal opening degrees in the engine of Fig. 1 are previously obtained by the experiment, etc. and these obtained amounts are memorized as target fuel injection amounts TQ as shown in Fig. 2 (A) in the unit 60 in the form of a map as a function of the accelerator pedal opening degree Dac. During the engine operation (i.e. during the operation of the engine), the target amount TQ is

acquired from the map of Fig. 2 (A) on the basis of the degree Dac. A fuel injector opening time (i.e. a time for opening the fuel injector for injecting the fuel from the fuel injector) necessary to make the injector inject the fuel having the acquired target amount TQ is calculated on the basis of the target amount TQ. The opening time of the injector is controlled in each intake stroke such that the injector is opened for the calculated time.

[0070] In the map of Fig.2(A), as the accelerator pedal opening degree Dac is large, the target fuel injection amount TQ is large.

[0071] Next, the control of the throttle valve of the first embodiment will be explained. In the first embodiment, suitable throttle valve opening degrees (i.e. opening degrees of the throttle valve) depending on the fuel injection amount and the engine speed (i.e. the rotation speed of the engine) in the engine of Fig. 1 are previously obtained by the experiment, etc. and these obtained degrees are memorized as target throttle valve opening degrees TDth as shown in Fig. 2 (B) in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. During the engine operation, the target degree TDth is acquired from the map of Fig. 2 on the basis of the fuel injection amount Q and the engine speed N. The opening degree of the throttle valve is controlled such that the throttle valve opens by this acquired target degree TDth.

[0072] In the map of Fig.2(B), as the fuel injection amount Q is large, the target degree TDth is large and as the engine speed N is large, the target degree TDth is large.

[0073] In the first embodiment, as the fuel injection amount Q used for acquiring the target degree TDth from the map of Fig.2(B), the target fuel injection amount TQ (i.e. the target amount TQ acquired from the map of Fig. 2(A)) is employed.

[0074] Next, the control of the opening degree of the EGR control valve by the control device of the first embodiment will be explained. In the first embodiment, suitable EGR rates (i.e. the mass rates of the exhaust gas included in the gas suctioned into the combustion chamber) depending on the fuel injection amount and the engine speed are previously obtained by the experiment, etc. and these obtained EGR rates are memorized as target EGR rates TRegr as shown in Fig. 2 (C) in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. During the engine operation, the target rate TRegr is acquired from the map of Fig. 2 (C) on the basis of the amount Q and the speed N. The EGR control valve opening degree (i.e. the opening degree of the EGR control valve) for accomplishing this acquired target rate TRegr is calculated as the target EGR control valve opening degree TDegr according to a predetermined calculation law. The opening degree of the EGR control valve is controlled such that the EGR control valve opens by this calculated target degree TDegr.

[0075] In the map of Fig.2(C), as the fuel injection

amount Q is large, the target EGR rate TRegr is small and as the engine speed N is large, the target EGR rate TRegr is small.

[0076] In the first embodiment, as shown in Fig.3, learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. During the engine operation, the learned value KG depending on the amount Q and the speed N is acquired from the map of Fig.3. The fuel injection amount obtained by adding this acquired learned value to the target fuel injection amount is used as the fuel injection amount for the target EGR rate acquisition (i.e. the fuel injection amount used for acquiring the target EGR rate TRegr from the map of Fig.2(C)) and as the fuel injection amount for the estimated air-fuel ratio calculation (i.e. the fuel injection amount used for calculating the estimated value of the air-fuel ratio of the mixture gas).

[0077] Next, the update of the above- explained learned value of the first embodiment will be explained. As explained above, in the first embodiment, as shown in Fig. 3, the learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. The initial values of all learned values KG are set as "1".

[0078] During the engine operation, a correction value is calculated every a predetermined condition is satisfied and new learned value KG obtained by adding this calculated correction value to the learned value KG of the map of Fig.3 corresponding to the current fuel injection amount Q (the current target fuel injection amount TQ is used as this amount Q) and the current engine speed N is memorized in the map of Fig.3 as the learned value corresponding to the current amount Q and the current speed N. That is, during the engine operation, the learned value KG of the map of Fig.3 corresponding to the current amount Q and the current speed N is updated by the correction value every the predetermined condition is satisfied.

[0079] Next, the calculation of the above- explained correction value of the first embodiment will be explained. In the first embodiment, every a predetermined condition is satisfied, the detected air- fuel ratio (i.e. the air- fuel ratio of the mixture gas calculated from the output value of the upstream oxygen concentration sensor) is acquired and the estimated air- fuel ratio is calculated. As explained above, the estimated air- fuel ratio is an estimated value of the air- fuel ratio of the mixture gas and is an air- fuel ratio of the mixture gas calculated by using the detected intake air amount (i.e. the intake air amount calculated from the output value of the air flow meter) and the fuel injection amount obtained by adding the learned value KG acquired from the map of Fig. 3 on the basis of the amount Q and the speed N to the target fuel injection amount TQ. A difference of the detected air- fuel ratio relative to the estimated air- fuel ratio (hereinafter, this difference will be referred to as-- air- fuel ratio difference--) is calculated. The correction value is calculated

on the basis of this calculated air- fuel ratio difference.

[0080] The correction value calculated when the air-fuel ratio difference is larger than zero (i.e. when the detected air-fuel ratio is smaller than the estimated air-fuel ratio) is positive and is calculated as a suitable value such that the detected air-fuel ratio does not become larger than the estimated air-fuel ratio when the fuel injection amount obtained by adding the learned value updated by the correction value in question is used as the fuel injection amount for the target EGR rate acquisition and as the fuel injection amount for the estimated air-fuel ratio calculation. On the other hand, the correction value calculated when the air-fuel ratio difference is smaller than zero (i.e. when the detected air-fuel ratio is larger than the estimated air-fuel ratio) is negative and is calculated as a suitable value such that the detected air-fuel ratio does not become smaller than the estimated air-fuel ratio when the fuel injection amount obtained by adding the learned value updated by the correction value in question to the target fuel injection amount is used as the fuel injection amount for the target EGR rate acquisition and as the fuel injection amount for the estimated air-fuel ratio calculation.

[0081] By using the fuel injection amount obtained by adding the learned value updated as explained above to the target fuel injection amount as the fuel injection amount for the target EGR rate acquisition and the fuel injection amount for the estimated air-fuel ratio calculation, the air-fuel ratio difference becomes small and finally, the air-fuel ratio difference becomes zero. Next, the reason thereof will be explained. Below, for facilitating the understanding, the reason will be explained assuming that there is no change of the target fuel injection amount and the engine speed.

[0082] In the case that the actual fuel injection amount corresponds to the target fuel injection amount and the detected intake air amount corresponds to the actual intake air amount (i.e. in the case that the fuel injectors and the air flow meter work normally), the detected air-fuel ratio corresponds to the air-fuel ratio of the mixture gas calculated by using the target fuel injection amount and the detected intake air amount (i.e. the estimated air-fuel ratio). On the other hand, in the case that the actual fuel injection amount does not correspond to the target fuel injection amount or the detected intake air amount does not correspond to the actual intake air amount (i.e. in the case that the fuel injector or the air flow meter does not work normally), the detected air-fuel ratio may correspond to the estimated air-fuel ratio, however, in general, the detected air-fuel ratio does not correspond to the estimated air-fuel ratio.

[0083] As explained above, in the first embodiment, when the detected air-fuel ratio is smaller than the estimated air-fuel ratio (i.e. when the detected air-fuel ratio is richer than the estimated air-fuel ratio), the positive correction value is calculated. This calculated value is added to the learned value KG of the map of Fig.3 corresponding to the current fuel injection amount Q and the

current engine speed N. The correction value is positive and therefore, the learned value KG becomes large. The fuel injection amount obtained by adding the learned value KG to the target fuel injection amount TQ is used as the fuel injection amount for the target EGR rate acquisition and therefore, the fuel injection amount for this acquisition becomes large. Therefore, the target EGR rate acquired from the map of Fig.2(C) becomes small and as a result, the intake air amount increases. Therefore, the detected air-fuel ratio becomes large.

[0084] At this time, as explained above, the intake air amount increases and therefore, the detected intake air amount becomes large. Therefore, when the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel ratio becomes large. However, in the first embodiment, the fuel injection amount obtained by adding the learned value to the target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value becomes large by the addition of the correction value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes large. Therefore, even when the detected intake air amount becomes large, the fuel injection amount for the estimated air-fuel ratio calculation becomes large and therefore, the increase degree of the estimated air-fuel ratio due to the increase of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes small.

[0085] As explained above, when the detected air-fuel ratio is smaller than the estimated air-fuel ratio, by the update of the learned value, the detected air-fuel ratio becomes large and the estimated air-fuel ratio becomes small (or the estimated air-fuel ratio does not change or the estimated air-fuel ratio becomes large only by the relatively small degree and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is smaller than the estimated air-fuel ratio (i.e. as far as the air-fuel ratio difference is larger than zero), the update of the learned value is repeatedly performed (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference finally becomes zero.

[0086] On the other hand, as explained above, when the detected air-fuel ratio is larger than the estimated ratio (i.e. when the detected air-fuel ratio is leaner than the estimated ratio), the negative correction value is calculated. This calculated correction value is added to the learned value KG of the map of Fig.3 corresponding to the current amount Q and the current speed N. The correction value is negative and therefore, the learned value KG becomes small. The fuel injection amount obtained by adding the learned value KG in question to the target fuel injection amount TQ is used as the fuel injection amount for target EGR rate acquisition and therefore, the fuel injection amount for this acquisition becomes small. Therefore, the target EGR rate acquired from the map of Fig.2(C) becomes large and as a result, the intake air

amount decreases. Therefore, detected air-fuel ratio becomes small.

[0087] On the other hand, as explained above, the intake air amount decreases and therefore, the detected intake air amount becomes small. Therefore, if the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel ratio becomes small. However, in the first embodiment, the fuel injection amount obtained by adding the learned value to the target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value in question has become small by adding the correction value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes small. Therefore, even when the detected intake air amount decreases, the fuel injection amount for the estimated air-fuel ratio calculation also becomes small, the decrease degree of the estimated air-fuel ratio due to the decrease of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes large.

[0088] As explained, when the detected air-fuel ratio is larger than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes small while the estimated air-fuel ratio becomes large (or the estimated air-fuel ratio does not change or changes only by the relatively small degree) and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is larger than the estimated ratio (i.e. as far as the air-fuel ratio difference is smaller than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become small). Thus, eventually, the air-fuel ratio difference becomes zero.

[0089] When the air-fuel ratio difference is zero, the detected air-fuel ratio corresponds to the estimated ratio and therefore, the update of the learned value is not needed. However, for the simplification of the control logic of the control device, when the air-fuel ratio difference is zero, the control logic for updating the learned value when the air-fuel ratio difference is not zero may be used. That is, when the air-fuel ratio difference is zero, the correction value is calculated as zero and new learned value KG obtained by adding this calculated correction value to the learned value KG of the map of Fig.3 corresponding to the current amount Q and the current speed N may be memorized in the map of Fig.3 as the learned value corresponding to the current amount Q and the current speed N.

[0090] Due to the cause other than the difference of the actual fuel injection amount relative to the target amount or the difference of the actual intake air amount relative to the detected amount, the air-fuel ratio difference may occur. In this case, when the excessive large air-fuel ratio difference occurs, the learned value becomes large excessively. Then, the target fuel injection amount is corrected excessively by the learned value and as a result, the target EGR rate is corrected excessively,

however, this is not preferred.

[0091] In the first embodiment, for avoiding the excessive correction of the EGR rate, a suitable value as an upper limit of the learned value (this is positive and hereinafter, will be referred to as --upper limit learned value--) and a suitable value as a lower limit of the learned value (hereinafter, this is negative and hereinafter, will be referred to as --lower limit learned value--) are set. When the learned value corrected by the correction value is positive and is larger than the upper limit learned value, the learned value is limited to the upper limit learned value. On the other hand, when the learned value corrected by the correction value is negative and is smaller than the lower limit learned value (i.e. the learned value and the lower limit learned value are negative and therefore, the absolute value of the learned value is larger than that of the lower limit learned value), the learned value is limited to the lower limit learned value.

[0092] Next, the setting of the upper and lower limit learned values in the first embodiment will be explained. In the first embodiment, in the case that among the fuel injection amount difference where the actual fuel injection amount becomes larger than the target amount, the fuel injection amount difference where the difference of the actual fuel injection amount relative to the target amount becomes large to the maximum extent (hereinafter, this difference will be referred to as-- maximum fuel injection amount increase difference--) occurs, the learned values obtained eventually by the update according to the above- explained process (i.e. the learned values when the air-fuel ratio difference becomes zero) are previously obtained depending on the target fuel injection amount and the fuel pressure (i.e. the pressure of the fuel supplied to the fuel injectors) . These obtained learned values are memorized in the unit 60 as maximum learned value MaxF due to the fuel injection amount difference in the form of a map as a function of the fuel injection amount Q and the fuel pressure Pf as shown in Fig. 4 (A) . These maximum learned values due to the fuel injection amount difference are positive.

[0093] Further, in the case that among the fuel injection amount difference where the actual fuel injection amount becomes smaller than the target amount, the fuel injection amount difference where the difference of the actual fuel injection amount relative to the target amount becomes large to the maximum extent (hereinafter, this difference will be referred to as-- maximum fuel injection amount decrease difference--) occurs, the learned values eventually obtained by the update according to the above- explained process are previously obtained depending on the target fuel injection amount and the fuel pressure. These obtained learned values are memorized in the unit 60 as minimum learned values MinF due to the fuel injection amount difference in the form of a map as a function of the fuel injection amount Q and the fuel pressure Pf as shown in Fig. 4 (B) . These minimum learned values due to the fuel injection amount difference are negative.

[0094] Further, in the case that among the intake air amount difference where the detected intake air amount (i.e. the intake air amount calculated on the output value of the air flow meter) becomes larger than the actual amount, the intake air amount difference where the difference of the detected intake air amount relative to the actual amount becomes large to the maximum extent (hereinafter, this difference will be referred to as-- maximum intake air amount increase difference--) occurs, the learned values eventually obtained by the update according to the above- explained process are previously obtained. These obtained learned values are memorized as maximum learned values MaxA due to the intake air amount difference in the form of a map as a function of the intake air amount Ga as shown in Fig. 4 (C) . These maximum learned values due to the intake air amount difference are positive.

[0095] Further, in the case that among the intake air amount difference where the detected intake air amount becomes smaller than the actual amount, the intake air amount difference where the difference of the detected intake air amount relative to the actual amount becomes large to the maximum extent (hereinafter, this difference will be referred to as-- maximum intake air amount decrease difference--) occurs, the learned values eventually obtained by the update according to the above- explained process are previously obtained depending on the intake air amount. These obtained learned values are memorized in the unit 60 as minimum learned values MinA due to the intake air amount difference in the form of a map as a function of the intake air amount Ga as shown in Fig. 4 (D) . These minimum learned values due to the intake air amount difference are negative.

[0096] Then, during the engine operation (i.e. during the operation of the engine), before the learned value is updated, the maximum and minimum learned values MaxF and MinF due to the fuel injection amount difference are acquired from the maps of Figs. 4 (A) and 4 (B) on the basis of the current amount Q and the pressure Pf, while the maximum and minimum learned values MaxA and MinA due to the intake air amount difference are acquired from the maps of Figs. 4 (C) and 4 (D) on the basis of the current amount Ga.

[0097] Then, the maximum learned values MaxF and MaxA due to the acquired fuel injection amount and intake air amount differences, respectively, are compared with each other and the larger maximum learned value among them is set as the current upper limit learned value. At the same time, the minimum learned values MinF and MinA due to the acquired fuel injection amount and intake air amount differences, respectively, are compared with each other. The smaller minimum learned value among them (i.e. these minimum learned values are negative, the minimum learned value having a larger absolute value among them) is set as the lower limit learned value.

[0098] In the first embodiment, one learned value is used as the learned value to be added to the target fuel

injection amount for calculating the fuel injection amount for the target EGR rate acquisition and as the learned value subtracted from the target fuel injection amount for calculating the fuel injection amount for the estimated air-fuel ratio calculation. That is, the learned value used for the calculation of the fuel injection amount for the target EGR rate acquisition and the learned value used for the calculation of the fuel injection amount for the estimated air-fuel ratio calculation are the same as each other. However, these learned values may be different from each other. In this case, as similar to the first embodiment, the upper and lower limit learned values regarding the learned values, respectively are set.

[0099] Next, an example of the routine for performing the control of the fuel injectors of the first embodiment will be explained. This example of the routine is shown in Fig. 5. The routine of Fig. 5 is performed every a predetermined time has elapsed.

[0100] When the routine of Fig.5 starts, first, at step 10, the accelerator pedal opening degree Dac is acquired. Next, at step 11, the target fuel injection amount TQ is acquired from the map of Fig.2(A) on the basis of the degree Dac acquired at step 10. Next, at step 12, the fuel injector opening time TO for making the fuel injector inject the fuel of the target amount TQ acquired at step 11 is calculated. Next, at step 13, the command value for making the fuel injector open for the time TO calculated at step 12 is output to the fuel injector and then, the routine is terminated.

[0101] Next, an example of the routine for performing the control of the throttle valve of the first embodiment will be explained. This example of the routine is shown in Fig. 6. The routine of Fig. 6 is performed every a predetermined time has elapsed.

[0102] When the routine of Fig.6 starts, first, at step 20, the fuel injection amount Q and the engine speed N are acquired. The amount Q acquired at step 20 is the target amount TQ acquired at step 11 of the routine of Fig.5. Next, at step 21, the target throttle valve opening degree TDth is acquired from the map of Fig.2(B) on the basis of the amount Q and the speed N acquired at step 20. Next, at step 22, the command value for accomplishing the target degree TDth acquired at step 21.

[0103] Next, an example of the routine for performing the control of the EGR control valve of the first embodiment will be explained. This example of the routine is shown in Fig. 7. The routine of Fig. 7 is performed every a predetermined time has elapsed.

[0104] When the routine of Fig.7 starts, first, at step 30, the fuel injection amount Q and the engine speed N are acquired. The amount Q acquired at step 30 is the target amount TQ acquired at step 11 of the routine of Fig.5. Next, at step 31, the learned value KG corresponding to the amount Q and the speed N acquired at step 30 among the learned values KG memorized in the unit 60 is acquired. Next, at step 32, the amount Q acquired at step 30 is corrected by adding the learned value KG acquired at step 31 to the amount Q acquired at step 30.

Next, at step 33, the target EGR rate TR_{egr} is acquired from the map of Fig.2(C) on the basis of the amount Q corrected at step 32 and the speed N acquired at step 30. Next, at step 34, the command value for accomplishing the target rate TR_{egr} acquired at step 33 is output to the EGR control valve and then, the routine is terminated.

[0105] Next, an example of the routine for performing the update of the learned value of the first embodiment will be explained. This example of the routine is shown in Fig.8. The routine of Fig.8 is performed every a predetermined time has elapsed.

[0106] When the routine of Fig.8 starts, first, at step 100, the fuel injection amount Q , the engine speed N , the intake air amount G_a , the detected air-fuel ratio A/F and the fuel pressure P_f are acquired. The acquired amount Q is the target amount TQ acquired at step 11 of the routine of Fig.5 and the acquired amount G_a is the detected intake air amount.

[0107] Next, at step 101, the learned value KG corresponding to the amount Q and the speed N acquired at step 100 is acquired from the map of Fig. 3, the maximum and minimum learned values $MaxF$ and $MinF$ due to the fuel injection amount difference corresponding to the amount Q and the pressure P_f acquired at step 100 are acquired from the map of Figs. 4 (A) and 4 (B), respectively and the maximum and minimum learned values $MaxA$ and $MinA$ due to the intake air amount difference corresponding to the amount G_a acquired at step 100 is acquired from the map of Figs. 4 (C) and 4 (D), respectively.

[0108] Next, at step 102, the larger maximum learned value among the maximum learned value $MaxF$ due to the fuel injection amount difference and the maximum learned value $MaxA$ due to the intake air amount difference acquired at step 101 is set as the upper limit learned value Max and the smaller minimum learned value among the minimum learned value $MinF$ due to the fuel injection amount difference and the minimum learned value $MinA$ due to the intake air amount difference acquired at step 101 is set as the lower limit learned value Min .

[0109] Next, at step 103, the fuel injection amount Q is corrected by adding the learned value KG acquired at step 101 to the amount Q acquired at step 100. Next, at step 104, the estimated air-fuel ratio A/F_{est} is calculated on the basis of the amount Q corrected at step 103 and the amount G_a acquired at step 100. Next, at step 105, the air-fuel ratio difference $\Delta A/F$ is calculated by subtracting the detected ratio A/F acquired at step 100 from the estimated ratio A/F_{est} calculated at step 104.

[0110] Next, at step 106, the correction value K is calculated on the basis of the difference $\Delta A/F$ calculated at step 105. The calculated correction value K is positive when the difference $\Delta A/F$ is positive, the calculated correction value K is negative when the difference $\Delta A/F$ is negative and the calculated correction value is zero when the difference $\Delta A/F$ is zero.

[0111] Next, at step 107, a provisional learned value KG_n is calculated by adding the correction value K calculated

at step 106 to the learned value KG acquired at step 101. Next, at step 108, it is judged if the provisional value KG_n calculated at step 107 is smaller than the lower limit value Min set at step 102 ($KG_n < Min$). When it is judged that $KG_n < Min$, the routine proceeds to step 109. On the other hand, it is judged that $KG_n \geq Min$, the routine proceeds to step 110.

[0112] When it is judged that $KG_n < Min$ at step 108 and then, the routine proceeds to step 109, the learned value KG is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speed N acquired at step 100 with the lower limit value Min and then, the routine is terminated. That is, when the provisional learned value KG_n is smaller than the lower limit value Min , the learned value KG is limited to the lower limit value Min .

[0113] On the other hand, when it is judged that $KG_n \geq Min$ at step 108 and then, the routine proceeds to step 110, it is judged if the provisional value KG_n calculated at step 107 is larger than the upper limit value Max set at step 102 ($KG_n > Max$). When it is judged that $KG_n > Max$, the routine proceeds to step 111. On the other hand, when it is judged that $KG_n \leq Max$, the routine proceeds to step 112.

[0114] When it is judged that $KG_n > Max$ at step 110 and then, the routine proceeds to step 111, the learned value KG is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speed N acquired at step 100 with the upper limit value Max and then, the routine is terminated. That is, when the provisional value KG_n is larger than the upper limit value Max , the learned value KG is limited to the upper limit value Max .

[0115] On the other hand, when it is judged that $KG_n \leq Max$ at step 110 and then, the routine proceeds to step 112, the learned value KG is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speed N acquired at step 100 with the provisional value KG_n calculated at step 107 and then, the routine is terminated. That is, when the provisional value KG_n is equal to or larger than the lower limit value Min and is equal to or smaller than the upper limit value Max , the provisional value KG_n is set as the learned value KG .

[0116] Next, the second embodiment of the invention will be explained. In the second embodiment of the invention, the constitution other than the setting of the upper and lower limit learned values is the same as that of the first embodiment. Therefore, below, only the setting of the upper and lower limit learned values of the second embodiment will be explained.

[0117] In the second embodiment, in the case that the maximum fuel injection amount increase difference and the maximum intake air amount increase difference occur, the learned values calculated according to the same process as that of the first embodiment are previously obtained depending on the fuel injection amount, the fuel pressure and the intake air amount and these learned

values are memorized in the unit 60 as the maximum learned values Max in the form of a map as a function of the fuel injection amount Q, the fuel pressure Pf and the intake air amount Ga as shown in Fig.9(A).

[0118] Further, in the case that the maximum fuel injection amount decrease difference and the maximum intake air amount decrease difference occur, the learned values calculated according to the same process as that of the first embodiment are previously obtained depending on the fuel injection amount, the fuel pressure and the intake air amount and these learned values are memorized in the unit 60 as the minimum learned values Min in the form of a map as a function of the fuel injection amount Q, the fuel pressure Pf and the intake air amount Ga as shown in Fig. 9 (B) .

[0119] Then, during the engine operation, the maximum and minimum learned values Max and Min are acquired from the maps of Figs. 9 (A) and 9 (B) on the basis of the current fuel injection amount, the fuel pressure and the intake air amount every a predetermined timing has come and these maximum and minimum learned values Max and Min are set as the upper and lower limit learned values, respectively.

[0120] The controls of the fuel injector, the throttle valve and the EGR control valve are performed by the routines of Figs.5, 6 and 7, respectively.

[0121] Next, an example of the routine for performing the update of the learned value of the second embodiment will be explained. This example of the routine is shown in Fig. 10. The routine of Fig. 10 is performed every a predetermined time has elapsed.

[0122] When the routine of Fig.10 starts, first, at step 200, the fuel injection amount Q, the engine speed N, the intake air amount Ga, the detected air-fuel ratio A/F and the fuel pressure Pf are acquired. The acquired amount Q is the target amount TQ acquired at step 11 of the routine of Fig. 5 and the acquired amount Ga is the detected intake air amount.

[0123] Next, at step 201, the learned value KG corresponding to the amount Q and the speed N acquired at step 200 is acquired from the map of Fig. 3 and the maximum and minimum learned values Max and Min corresponding to the amount Q, the pressure Pf and the amount Ga acquired at step 100 are acquired from the maps of Figs. 9 (A) and 9 (B), respectively.

[0124] Next, at step 202, the maximum and minimum learned values Max and Min acquired at step 201 are set to the upper and lower limit learned values Max and Min, respectively.

[0125] Next, at step 203, the fuel injection amount Q is corrected by adding the learned value KG acquired at step 201 to the amount Q acquired at step 200. Next, at step 204, the estimated air- fuel ratio A/ Fest is calculated on the basis of the amount Q corrected at step 203 and the amount Ga acquired at step 200. Next, at step 205, the air- fuel ratio difference $\Delta A/F$ is calculated by subtracting the detected ratio A/F acquired at step 200 from the estimated ratio A/ Fest calculated at step 204.

[0126] Next, at step 206, the correction value K is calculated on the basis of the difference $\Delta A/F$ calculated at step 205. The calculated correction value K is positive when the difference $\Delta A/F$ is positive, the calculated correction value is negative when the difference $\Delta A/F$ is negative and the calculated correction value K is zero when the difference $\Delta A/F$ is zero.

[0127] Next, at step 207, the provisional learned value KGn is calculated by adding the correction value K calculated at step 206 to the learned value KG acquired at step 201. Next, at step 208, it is judged if the provisional value KGn calculated at step 207 is smaller than the lower limit value Min set at step 202 ($KGn < Min$) . When it is judged that $KGn < Min$, the routine proceeds to step 209. On the other hand, when it is judged that $KGn \geq Min$, the routine proceed to step 210.

[0128] When it is judged that $KGn < Min$ at step 208 and then, the routine proceeds to step 209, the learned value K is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speeds N acquired at step 200 with the minimum limit value Min and then, the routine is terminated. That is, when the provisional value KGn is smaller than the minimum limit value Min, the learned value KG is limited to the lower limit value Min.

[0129] On the other hand, when it is judged that $KGn \geq Min$ at step 208 and then, the routine proceeds to step 210, it is judged if the provisional value KGn calculated at step 207 is larger than the upper limit value Max set at step 202 ($KGn > Max$). When it is judged that $KGn > Max$, the routine proceeds to step 211. On the other hand, when it is judged that $KGn \leq Max$, the routine proceeds to step 212.

[0130] When it is judged that $KGn > Max$ at step 210 and then, the routine proceeds to step 211, the learned value KG is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speed N acquired at step 200 with the upper limit value Max and then, the routine is terminated. That is, when the provisional value KGn is larger than the upper limit value Max, the learned value KG is limited to the upper limit value Max.

[0131] On the other hand, when it is judged that $KGn \leq Max$ and then, the routine proceeds to step 212, the learned value KG is updated by replacing the learned value KG of the map of Fig.3 corresponding to the amount Q and the speed N acquired at step 200 with the provisional value KGn calculated at step 207 and then, the routine is terminated. That is, when the provisional value KGn is equal to or larger than the lower limit value Min and is equal to or smaller than the upper limit value Max, the provisional value KG is set as the learned value KG.

[0132] The above- explained embodiment is one in the case that the invention is applied to the engine comprising the EGR device. The invention can be applied to the engine not comprising the EGR device. Next, the embodiment in the case that the invention is applied to the engine not comprising the EGR device (hereinafter, this embod-

iment will be referred to as-- third embodiment--) will be explained.

[0133] The engine of the third embodiment is shown in Fig.11. Except that the engine does not comprise the EGR device, the constitution of the third embodiment is the same as that of the first embodiment and therefore, the explanation thereof will be omitted.

[0134] The control of the fuel injector of the third embodiment will be explained. In the third embodiment, suitable fuel injection amounts corresponding to the accelerator pedal opening degrees in the engine of Fig.11 are previously obtained by the experiment, etc. and these obtained amounts are memorized as the target fuel injection amounts TQ in the unit 60 in the form of a map as a function of the accelerator pedal opening degree Dac as shown in Fig.12(A). Then, during the engine operation, the target amount TQ is acquired from the map of Fig.12 (A) on the basis of the degree Dac. The fuel injector opening time necessary to inject the fuel of the acquired target amount TQ from the fuel injector is calculated on the basis of the target amount TQ. The opening time of the fuel injector is controlled at each intake stroke such that the injector opens for the calculated opening time.

[0135] In the map of Fig.12(A), as the degree Dac is large, the target amount Q is large.

[0136] Next, the control of the throttle valve of the third embodiment will be explained. In the third embodiment, suitable throttle valve opening degrees depending on the fuel injection amount and the engine speed in the engine of Fig. 11 are previously obtained by the experiment, etc. and these obtained opening degrees are memorized as target throttle valve opening degrees TDth in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N as shown in Fig. 12 (B) . Then, during the engine operation, the target degree TDth is acquired from the map of Fig. 12 (B) on the basis of the amount Q and the speed N. The opening degree of the throttle valve is controlled such that the throttle valve opens by the acquired target degree TDth.

[0137] In the map of Fig.12(B), as the amount Q is large, the target degree TDth is large and as the speed N is large, the target degree TDth is large.

[0138] In the third embodiment, as shown in Fig.13, the learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. During the engine operation, the learned value KG corresponding to the amount Q and the speed N is acquired from the map of Fig.13. The fuel injection amount obtained by adding this acquired learned value to the target fuel injectino amount is used as the fuel injection amount for the target throttle valve opening degree acquisition (i.e. the fuel injection amount used for acquireing the target degree TDth from the map of Fig.12(B)) and as the fuel injection amount for the estimated air-fuel ratio calculation.

[0139] In the third embodiment, the update of the learned value and the calculation of the correction value are performed according the same processes as those

of the first embodiment. In the third embodiment, the correction value calculated when the air-fuel ratio difference is larger than zero (i.e. when the detected air-fuel ratio is smaller than the estimated ratio) is calculated as a suitable positive value such that the detected air-fuel ratio does not become larger than the estimated ratio when the fuel injection amount obtained by adding the learned value updated by the correction value to the target fuel injection amount is used as the fuel injection amounts for the target throttle valve opening degree acquisition and the target throttle valve opening degree acquisition. On the other hand, in the third embodiment, the correction value calculated when the air-fuel ratio difference is smaller than zero (i.e. when the detected air-fuel ratio is larger than the estimated ratio) is calculated as a suitable negative value such that the detected air-fuel ratio does not becomes smaller than the estimated ratio when the fuel injection amount obtained by adding the learned value updated by the correction value to the target fuel injection amount is used as the fuel injection amounts for target throttle valve opening degree acquisition and the estimated air-fuel ratio calculation.

[0140] By using the fuel injection amount obtained by adding the learned value updated as explained above to the target fuel injection amount as the fuel injection amounts for the target throttle valve opening degree acquisition and the estimated air-fuel ratio calculation, the air-fuel ratio difference becomes small and eventually, the air-fuel ratio difference becomes zero. Next, the reason thereof will be explained. Below, for facilitating the understanding, the reason will be explained assuming that the target fuel injection amount and the engine speed do not change.

[0141] In the third embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment and therefore, the positive correction value is calculated when the detected air-fuel ratio is smaller than the estmated ratio (i.e. when the detected air-fuel ratio is richer than the estimated ratio). This calculated correction value is added to the learned value KG of the map of Fig.13 corresponding to the current amount Q and the current speed N. The correction value is positive and therefore, the learned value KG becomes large. The fuel injection amount obtained by adding the learned value KG to the target amount TQ is used as the fuel injection amount for the target throttle valve opening degree acquisition and therefore, the fuel injection amount for this acquisition becomes large. Therefore, the target throttle valve opening degree acquired from the map of Fig.12(B) becomes large and as a result, the intake air amount increases. Therefore, the detected air-fuel ratio becomes large.

[0142] On the other hand, at this time, as explained above, the intake air amount increases and therefore, the detected intake air amount becomes large. Therefore, if the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel

ratio becomes large. In this regard, in the third embodiment, the fuel injection amount acquired by adding the learned value to the target amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value has become large by adding the correction value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes large. Therefore, even if the detected intake air amount becomes large, the fuel injection amount for the estimated air-fuel ratio calculation becomes large and therefore, the increase degree of the estimated air-fuel ratio due to the increase of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes small.

[0143] As explained above, when the detected air-fuel ratio is smaller than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes large and the estimated air-fuel ratio becomes small (or does not change or becomes large by the relatively small degree) and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is smaller than the estimated air-fuel ratio (i.e. as far as the air-fuel ratio difference is larger than zero), the update of the learned value is repeatedly performed (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0144] On the other hand, in the third embodiment, when the detected air-fuel ratio is larger than the estimated ratio (i.e. when the detected air-fuel ratio is leaner than the estimated ratio), the negative correction value is calculated. This calculated value is added to the learned value KG of the map of Fig.13 corresponding to the current amount Q and the current speed N. The correction value is negative and therefore, the learned value KG becomes small. The fuel injection amount obtained by adding the learned value KG to the target fuel injection amount TQ is used as the fuel injection amount for the target throttle valve opening degree acquisition and therefore, the fuel injection amount for this acquisition becomes small. Therefore, the target throttle valve opening degree acquired from the map of Fig.12(B) becomes small and as a result, the intake air amount decreases. Therefore, the detected air-fuel ratio becomes small.

[0145] On the other hand, as explained above, the intake air amount decreases and therefore, the detected intake air amount becomes small. Therefore, if the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel ratio becomes small. In the third embodiment, the fuel injection amount obtained by adding the learned value to the target amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value has become small by adding the learned value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes small. Therefore, even if the detected intake air amount becomes small, the fuel injection amount for the estimated air-fuel ratio calculation

becomes small and therefore, the decrease degree of the estimated air-fuel ratio due to the decrease of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes large.

[0146] As explained above, when the detected air-fuel ratio is larger than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes small and the estimated air-fuel ratio becomes large (or does not change or becomes small by the relatively small degree) and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is larger than the estimated ratio (i.e. as far as the air-fuel ratio difference is smaller than zero), the update of the learned value is repeatedly performed (i.e. the learned value continues to become small). Thus, the air-fuel ratio difference becomes zero eventually.

[0147] As explained relating to the first embodiment, in the case that the learned value becomes large excessively, the target fuel injection amount is corrected excessively by the learned value and as a result, the target throttle valve opening degree is corrected excessively and this is not preferred.

[0148] In the third embodiment, for avoiding the excessive correction of the throttle valve opening degree, a value suitable as the upper limit of the learned value (this value is positive and hereinafter, will be referred to as --upper limit learned value--) is set and a value suitable as the lower limit of the learned value (this value is negative and hereinafter, will be referred to as --lower limit learned value--) is set. When the learned value corrected by the correction value is positive and is larger than the upper limit learned value, the learned value is limited to the upper limit learned value. On the other hand, when the learned value corrected by the correction value is negative and is smaller than the lower limit learned value (i.e. when the absolute value of the learned value is larger than that of the lower limit learned value, since the learned value and the lower limit learned value are negative), the learned value is limited to the lower limit learned value.

[0149] The setting of the upper and lower limit learned values of the third embodiment is performed according to the same processes as that of the first embodiment. However, when the maximum fuel injection amount increase amount occurs, the maximum learned value due to the fuel injection amount difference of the third embodiment is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease difference occurs, the minimum learned value due to the fuel injection amount difference of the third embodiment is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the fuel injection amount and the fuel pressure. Further, when the maximum intake air

amount increase difference occurs, the maximum learned value due to the intake air amount difference is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount. Further, when the maximum intake air amount decrease difference occurs, the minimum learned value due to the intake air amount difference is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount.

[0150] Further, the setting of the upper and lower limit learned values of the third embodiment may be performed according to the same processes as those of the second embodiment. However, when the maximum fuel injection amount and intake air amount increase differences occur, the maximum learned value is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount, the fuel pressure and the intake air amount. Further, when the maximum fuel injection amount and intake air amount decrease differences occur, the minimum value is a value obtained eventually by the update according to the third embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount, the fuel pressure and the intake air amount.

[0151] In the third embodiment, one learned value is used as the learned values to be added to the target fuel injection amount for calculating the fuel injection amounts for the target throttle valve opening degree acquisition and the estimated air-fuel ratio calculation, respectively. That is, the learned values used for the calculation of the fuel injection amounts for the target throttle valve opening degree acquisition and the estimated air-fuel ratio calculation, respectively are the same as each other. However, these learned values may be different from each other. In this case, the upper and lower limit learned values regarding the learned values are set similar to the first embodiment.

[0152] The control of the fuel injector of the third embodiment is, for example, performed by the routine of Fig. 5. In the case that the routine of Fig. 5 is used for the control of the injector of the third embodiment, at step 11, the fuel injection amount TQ is acquired from the map of Fig. 12(A).

[0153] Next, an example of the routine for performing the control of the throttle valve of the third embodiment will be explained. This example of the routine is shown in Fig. 14. The routine of Fig. 14 is performed every a predetermined time has elapsed.

[0154] When the routine of Fig. 14 starts, first, at step 40, the fuel injection amount Q and the engine speed N are acquired. The amount Q acquired at step 40 is the target amount TQ acquired at step 11 of the routine of Fig. 5. Next, at step 41, among the learned values KG memorized in the unit 60, the learned value KG corresponding to the amount Q and the speed N acquired at

step 40 is acquired. Next, at step 42, the amount Q acquired at step 40 is corrected by adding the learned value KG acquired at step 41 to the amount Q acquired at step 40. Next, at step 43, the target throttle valve opening degree TDth is acquired from the map of Fig. 2(B) on the basis of the amount Q corrected at step 42 and the speed N acquired at step 40. Next, at step 44, the command value for accomplishing the target degree TDth acquired at step 43 is output to the throttle valve and then, the routine is terminated.

[0155] The update of the learned value of the third embodiment is, for example, performed by the routines of Figs. 8 and 10. However, in the case that the routine of Fig. 8 is used for the update of the learned value of the third embodiment, the learned value KG acquired at step 101 of Fig. 8 is the learned value of the map of Fig. 13 corresponding to the amount Q and the speed N acquired at step 100, the maximum and minimum learned values MaxF and MinF acquired at step 101 of Fig. 8 are the above-explained maximum and minimum learned values due to the fuel injection amount difference of the third embodiment, respectively and the maximum and minimum learned values MaxA and MinA acquired at step 101 of Fig. 8 are the above-explained maximum and minimum learned values due to the intake air amount difference of the third embodiment, respectively. Further, in the case that the routine of Fig. 10 is used for the update of the learned value of the third embodiment, the learned value KG acquired at step 201 is the learned value of the map of Fig. 13 corresponding to the amount Q and the speed N acquired at step 200 and the maximum and minimum learned values Max and Min acquired at step 201 of Fig. 10 are the above-explained maximum and minimum learned values of the third embodiment.

[0156] The above-explained embodiments are those in the case that the invention is applied to the engine with no supercharger. However, the invention can be applied to the engine with the supercharger. Next, the embodiment in the case that the invention is applied to the engine with the supercharger (hereinafter, this will be referred to as-- fourth embodiment--) will be explained.

[0157] The engine of the fourth embodiment is shown in Fig. 15. The constitution of the engine of the fourth embodiment is the same as that of the first embodiment except that the engine comprises a supercharger 33 and does not comprise the EGR device.

[0158] The engine 10 shown in Fig. 15 comprises the supercharger 35. The supercharger 35 has a compressor 35A positioned in the intake pipe 32 upstream of the intercooler 34 and an exhaust turbine 35 positioned upstream of the catalytic converter 43. As shown in Fig. 16, the exhaust turbine 35B has an exhaust turbine body 35C and a plurality of vanes 35D.

[0159] The turbine 35B (in particular, the turbine body 35C) is connected to the compressor 35A by a shaft (not shown). When the turbine body 35C is rotated by the exhaust gas, the rotation thereof is transmitted to the compressor 35A via the shaft and thereby, the compres-

sor 35A is rotated. The gas in the intake pipe 32 downstream of the compressor is compressed by the rotation of the compressor 35A and as a result, the pressure of the gas (hereinafter, this pressure will be referred to as-- supercharged pressure--) increases.

[0160] On the other hand, the vanes 35D are positioned radially at the constant angular intervals about the rotation central axis R1 of the turbine body such that they surround the turbine body 35C. Each vane 35D is positioned such that it can rotate about a corresponding axis shown by the symbol R2 in Fig. 16. When the direction of the extending of each vane 35D (i.e. the direction shown by the symbol E in Fig. 16) is referred to as-- extending direction-- and the line connecting the rotation central axis R1 of the turbine body 35C to the rotation axis R2 of the vane 35D (i.e. the line shown by the symbol A in Fig. 16) is referred to as-- base line- -, each vane 35D is rotated such that regarding all vanes 35D, the angles, each of which is defined between the extending direction thereof and the corresponding base line A, are the same as one another. When each vane 35D is rotated such that the angle between its extending direction E and the corresponding base line A becomes small, that is, such that the flow passage area between the adjacent vanes 35D becomes small, the pressure in the exhaust passage 40 (hereinafter, this pressure will be referred to as-- exhaust pressure--) upstream of the turbine body 35C increases and as a result, the flow velocity of the exhaust gas supplied to the turbine body 35C increases. Thus, the rotation speed of the turbine body 35C increases and as a result, the rotation speed of the compressor 35A increases and therefore, the gas flowing through the intake pipe 32 is considerably compressed by the compressor 35A. Thus, as the angle between the extending direction E of each vane 35D and the corresponding base line (hereinafter, this angle will be referred to as-- vane opening degree--) becomes small, the degree of the compression of the gas flowing through the intake pipe 32 by the compressor 35A becomes large (i.e. the supercharged pressure becomes high) .

[0161] Therefore, the supercharger 35 can control the supercharged pressure variably by controlling the operation condition (in particular, the vane opening degree) of the vane 35D.

[0162] The vanes 35D are connected to the interface 65 of the unit 60 and the control signal for controlling the operation of the vanes 35D is given thereto from the unit 60 via the interface 65.

[0163] Next, the control of the fuel injector of the fourth embodiment will be explained. In the fourth embodiment, in the engine shown in Fig.15, suitable fuel injection amounts depending on the accelerator pedal opening degrees are previously obtained by the experiment, etc. and these obtained amounts are memorized as target fuel injection amounts TQ in the unit 60 in the form of a map as a function of the accelerator pedal opening degree Dac as shown in Fig.17(A). Then, during the engine operation, the target amount TQ is acquired from the map

of Fig.17(A) on the basis of the degree Dac. The fuel injector opening time necessary to inject the fuel of the acquired target amount TQ from the injector is calculated on the basis of the target amount TQ. The opening time of the injector is controlled at each intake stroke such that the fuel injector opens for the calculated fuel injector opening time.

[0164] In the map of Fig.17(A), as the degree Dac is large, the target amount TQ is large.

[0165] Next, the control of the throttle valve of the fourth embodiment will be explained. In the fourth embodiment, in the engine shown in Fig. 15, suitable throttle valve opening degrees depending on the fuel injection amount and the engine speed are previously obtained by the experiment, etc. and these obtained degrees are memorized as target throttle valve opening degrees TDth in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N as shown in Fig. 17 (B) . Then, during the engine operation, the target degree TDth is acquired from the map of Fig. 17 (B) on the basis of the amount Q and the speed N. Then, the opening degree of the throttle valve is controlled such that the throttle valve opens by the acquired degree TDth.

[0166] In the map of Fig.17(B), as the amount Q is large, the target degree TDth is large and as the engine speed is large, the target degree TDth is large.

[0167] In the fourth embodiment, the target amount TQ (i.e. the target amount TQ acquired from the map of Fig. 17(A)) is employed as the fuel injection amount used for acquiring the target degree TDth from the map of Fig.17 (B).

[0168] Next, the control of the vanes of the fourth embodiment will be explained. In the fourth embodiment, in the engine shown in Fig. 15, suitable vane opening degrees (i.e. the opening degrees of the vane) depending on the fuel injection amount and the engine speed are previously obtained by the experiment, etc. and these obtained degrees are memorized as target vane opening degrees TDv in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. Then, during the engine operation, the target degree TDv is acquired from the map of Fig. 17 (C) on the basis of the amount Q and the speed N. Then, the opening degrees of the vanes are controlled such that the vanes open by the acquired target degree TDv.

[0169] In the map of Fig.17(C), as the amount Q is large, the target degree TDv is small and as the speed N is large, the target degree TDv is small.

[0170] In the fourth embodiment, as shown in Fig.18, the learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N. Then, during the engine operation, the learned value KG corresponding to the amount Q and the speed N is acquired from the map of Fig.18. Then, fuel injection amount obtained by adding this acquired learned value to the target fuel injection amount is used as the fuel injection amount for the target vane opening degree acquisition (i.e. the fuel injection

amount used for acquiring the target vane opening degree TDv from the map of Fig. 17(C)) and as the fuel injection amount for the estimated air-fuel ratio calculation.

[0171] In the fourth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment. However, in the fourth embodiment, the correction value when the air-fuel ratio difference is larger than zero (i.e. when the detected air-fuel ratio is smaller than the estimated ratio) is calculated as a suitable positive value such that the detected air-fuel ratio does not become larger than the estimated ratio when the fuel injection amount obtained by adding the learned value updated by the correction value to the target fuel injection amount is used as the fuel injection amounts for the target vane opening degree acquisition and for the estimated air-fuel ratio calculation. On the other hand, in the fourth embodiment, the correction value calculated when the air-fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air-fuel ratio does not become smaller than the estimated ratio when the fuel injection amount obtained by adding the learned value updated by the correction value to the target fuel injection amount is used as the fuel injection amounts for the target vane opening degree acquisition and for the estimated air-fuel ratio calculation.

[0172] By using the fuel injection amount obtained by adding the learned value updated as explained above to the target fuel injection amount as the fuel injection amounts for the target vane opening degree acquisition and for the estimated air-fuel ratio calculation, the air-fuel ratio difference becomes small and eventually, the air-fuel ratio difference becomes zero. Next, the reason thereof will be explained. Below, for facilitating the understanding, the reason will be explained assuming that the target fuel injection amount and the engine speed do not change.

[0173] In the fourth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment and therefore, the positive correction value is calculated when the detected air-fuel ratio is smaller than the estimated ratio (i.e. when the detected air-fuel ratio is richer than the estimated ratio). Then, this calculated correction value is added to the learned value KG of the map of Fig. 18 corresponding to the current fuel injection amount Q and the engine speed N. The correction value is positive and therefore, the learned value KG becomes large. The fuel injection amount obtained by adding the learned value KG to the target fuel injection amount TQ is used as the fuel injection amount for the target vane opening degree acquisition and therefore, the fuel injection amount for this acquisition becomes large. Therefore, the target vane opening degree acquired from the map of Fig. 17(C) becomes small and as a result, the intake air amount increases. Therefore, the detected air-fuel ratio becomes large.

[0174] On the other hand, at this time, as explained above, the intake air amount increases and therefore, the detected intake air amount becomes large. Therefore, if the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel ratio becomes large. In the fourth embodiment, the fuel injection amount obtained by adding the learned value to the target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value becomes large by adding the correction value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes large. Therefore, even when the detected intake air amount becomes large, the fuel injection amount for the estimated air-fuel ratio calculation becomes large and therefore, the increase degree of the estimated air-fuel ratio due to the increase of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes small.

[0175] As explained above, when the detected air-fuel ratio is smaller than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes large and the estimated air-fuel ratio becomes small (or does not change or becomes large by the relatively small degree) and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is smaller than the estimated ratio (i.e. as far as the air-fuel ratio difference is larger than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0176] On the other hand, in the fourth embodiment, when the detected air-fuel ratio is larger than the estimated ratio (i.e. the detected air-fuel ratio is leaner than the estimated ratio), the negative correction value is calculated. Then, this calculated correction value is added to the learned value KG of the map of Fig. 18 corresponding to the current amount Q and the speed N. The correction value is negative and therefore, the learned value KG becomes small. Then, the fuel injection amount obtained by adding the learned value KG to the target fuel injection amount TQ is used as the fuel injection amount for the target vane opening degree acquisition and therefore, the fuel injection amount for this acquisition becomes small. Therefore, the target vane opening degree acquired from the map of Fig. 17(C) becomes large and as a result, the intake air amount decreases. Therefore, the detected air-fuel ratio becomes small.

[0177] On the other hand, as explained above, the intake air amount decreases and therefore, the detected intake air amount becomes small. Therefore, if the fuel injection amount for the estimated air-fuel ratio calculation does not change, the estimated air-fuel ratio becomes small. In the fourth embodiment, the fuel injection amount obtained by adding the learned value to the target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the

learned value becomes small by adding the correction value thereto and therefore, the fuel injection amount for the estimated air-fuel ratio calculation becomes small. Therefore, even when the detected intake air amount becomes small, the fuel injection amount for the estimated air-fuel ratio calculation becomes small and therefore, the decrease degree of the estimated air-fuel ratio due to the decrease of the detected intake air amount becomes small or zero (i.e. the estimated air-fuel ratio does not change) or the estimated air-fuel ratio becomes large.

[0178] As explained above, when the detected air-fuel ratio is larger than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes small and the estimated air-fuel ratio becomes large (or does not change or becomes small by the relatively small degree) and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is larger than the estimated ratio (i.e. as far as the air-fuel ratio difference is smaller than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become small). Thus, the air-fuel ratio difference becomes zero eventually.

[0179] As explained relating to the first embodiment, in the case that the learned value becomes large excessively, the target fuel injection amount is corrected excessively by the learned value and as a result, the target vane opening degree is corrected excessively, however, this is not preferred.

[0180] In the fourth embodiment, for avoiding the excessive correction of the vane opening degree, a value suitable as the upper limit of the learned value (this suitable value is positive and hereinafter, will be referred to as --upper limit learned value--) and a value suitable as the lower limit of the learned value (this suitable value is negative and hereinafter, will be referred to as --lower limit learned value--) are set. When the learned value corrected by the correction value is positive and is larger than the upper limit learned value, the learned value is limited to the upper limit learned value. On the other hand, when the learned value corrected by the correction value is negative and is smaller than the lower limit learned value (i.e. when the absolute value of the learned value is larger than that of the lower limit learned value, since the learned value and lower limit learned value are negative), the learned value is limited to the lower limit learned value.

[0181] The setting of the upper and lower limit learned values of the fourth embodiment is performed according to the same process as that of the first embodiment. However, when the maximum fuel injection amount increase difference occurs, the maximum learned value due to the fuel injection amount difference of the fourth embodiment is a value obtained eventually by the update according to the first embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease difference occurs, the minimum learned value due to the fuel injection

amount difference of the fourth embodiment is a value obtained eventually by the update according to the fourth embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount and the fuel pressure. Further, when the maximum intake air amount increase difference occurs, the maximum learned value due to the intake air amount difference is a value obtained eventually by the update according to the fourth embodiment and is memorized in the unit 60 in the form of a map as a function of the actual intake air amount. Further, when the maximum intake air amount decrease difference occurs, the minimum learned value due to the intake air amount difference obtained eventually by the update according to the fourth embodiment and is memorized in the unit 60 in the form of a map as a function of the actual intake air amount.

[0182] The setting of the upper and lower limit learned values of the fourth embodiment may be performed according to the same process as that of the second embodiment. However, when the maximum fuel injection amount increase and intake air amount increase differences occur, the maximum learned value is a value obtained eventually by the update according to the fourth embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease and intake air amount decrease differences occur, the minimum learned value is a value obtained eventually by the update according to the fourth embodiment and is memorized in the unit 60 in the form of a map as a function of the target fuel injection amount, the fuel pressure and the intake air amount.

[0183] In the fourth embodiment, one learned value is used as the learned value to be added to the target fuel injection amount for calculating the fuel injection amount for the target vane opening degree acquisition and as the learned value to be subtracted from the target fuel injection amount for calculating the fuel injection amount for the estimated air-fuel ratio calculation. That is, the learned values used for the calculation of the fuel injection amounts for the target vane opening degree acquisition and for the estimated air-fuel ratio calculation are the same as each other. However, these learned values may be different from each other. In this case, the upper and lower limit learned values regarding the learned values are set similar to the first embodiment.

[0184] The control of the fuel injector of the fourth embodiment is, for example, performed by the routine of Fig. 5. However, in the case that the routine of Fig.5 is used for the control of the fuel injector of the fourth embodiment, at step 11, the target fuel injection amount TQ is acquired from the map of Fig.17(A).

[0185] The control of the throttle valve of the fourth embodiment is, for example, performed by the routine of Fig.6. However, in the case that the routine of Fig.6 is used for the control of the throttle valve of the fourth embodiment, at step 21, the target throttle valve opening degree TDth is acquired from the map of Fig.17(B).

[0186] Next, an example of the routine for performing the control of the vane of the fourth embodiment will be explained. This example of the routine is shown in Fig. 19. The routine of Fig. 19 is performed every a predetermined time has elapsed.

[0187] When the routine of Fig.19 starts, first, at step 50, the fuel injection amount Q and the engine speed N are acquired. The amount Q acquired at step 50 is the target amount TQ acquired at step 11 of the routine of Fig.5. Next, at step 51, among the learned values KG memorized in the unit 60, the learned value KG corresponding to the amount Q and the speed N acquired at step 50 is acquired. Next, at step 52, the amount Q acquired at step 50 is corrected by adding the value KG acquired at step 51 to the amount Q acquired at step 50. Next, at step 53, the target vane opening degree TDv is acquired from the map of Fig.2(C) on the basis of the amount Q corrected at step 52 and the speed N acquired at step 50. Next, at step 54, the command value for accomplishing the target degree TDv acquired at step 53 is output to the vanes and then, the routine is terminated.

[0188] The update of the learned value of the fourth embodiment is, for example, performed by the routine of Fig.8 or 10. However, in the case that the routine of Fig. 8 is used for the update of the learned value of the fourth embodiment, the learned value KG acquired at step 101 of Fig.8 is the learned value of the map of Fig.18 corresponding to the amount Q and the speed N acquired at step 100, the maximum and minimum learned values MaxF and MinF acquired at step 101 of Fig.8 are the above-explained maximum and minimum learned values due to the fuel injection amount difference of the fourth embodiment, respectively and the maximum and minimum learned values MaxA and MinA acquired at step 101 of Fig.8 are the above-explained maximum and minimum learned values due to the intake air amount difference of the fourth embodiment, respectively. Further, in the case that the routine of Fig.10 is used for the update of the learned value of the fourth embodiment, the learned value KG acquired at step 201 is the learned value of the map of Fig.18 corresponding to the amount Q and the speed N acquired at step 200 and the maximum and minimum learned values Max and Min acquired at step 201 of Fig.10 are the above-explained maximum and minimum learned values of the fourth embodiment, respectively.

[0189] The above- explained embodiments are those in the case that the invention is applied to the control device which corrects the intake air amount eventually by the learned value. However, the invention can be applied to the control device which corrects the fuel injection amount eventually by the learned value. Next, the embodiment in the case that the invention is applied to such a control device (hereinafter, this embodiment will be referred to as-- fifth embodiment--) will be explained. The engine of the fifth embodiment is the above- explained engine shown in Fig. 1 and therefore, the explanation of the constitution thereof will be omitted.

[0190] First, the control of the fuel injector of the fifth embodiment will be explained. In the fifth embodiment, as shown in Fig. 20, the learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N.

[0191] In the fifth embodiment, during the engine operation, the target fuel injection amount TQ is acquired from the map of Fig.2(A) on the basis of the accelerator pedal opening degree Dac. Then, the learned value KG corresponding to the amount Q (the target amount TQ is used as this amount Q) and the speed N is acquired from the map of Fig.20. The fuel injection amount obtained by subtracting the above-mentioned learned value KG from the acquired target amount (hereinafter, this amount will be referred to as initial target fuel injection amount--) TQ is set as the target fuel injection amount for the fuel injector opening time calculation (i.e. the target fuel injection amount used for calculating the fuel injector opening time). Then, the fuel injector opening time necessary to inject the fuel of the set target fuel injection amount for the fuel injector opening time from the injector is calculated on the basis of the target fuel injection amount. Then, the opening time of the fuel injector is controlled such that the injector opens for the calculated fuel injector opening time.

[0192] The control of the throttle valve of the fifth embodiment is the same as that of the first embodiment and therefore, the explanation thereof will be omitted.

[0193] Next, the control of the EGR control valve of the fifth embodiment will be explained. In the fifth embodiment, during the engine operation, the target EGR rate TRegr is acquired from the map of Fig. 2 (C) on the basis of the amount Q and the speed N. Then, the EGR control valve opening degree for accomplishing the acquired target rate TRegr is calculated as the target EGR control valve opening degree TDegr according to a predetermined calculation rule. Then, the opening degree of the EGR control valve is controlled such that the EGR control valve opens by this calculated target degree TDegr.

[0194] In the fifth embodiment, the initial target fuel injection amount TQ (i.e. the target amount TQ acquired from the map of Fig.2(A)) is used as the fuel injection amount for the target EGR rate acquisition).

[0195] Further, in the fifth embodiment, the initial target fuel injection amount TQ (i.e. the target amount TQ acquired from the map of Fig. 2 (A)) is used as the fuel injection amount for the estimated air- fuel ratio calculation.

[0196] In the fifth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment. However, in the fifth embodiment, the correction value calculated when the air-fuel ratio difference is larger than zero (i.e. when the detected air-fuel ratio is smaller than the estimated ratio) is calculated as a suitable positive value such that the detected air-fuel ratio does not becomes larger than the estimated ratio when the fuel injection amount obtained by subtract-

ing the learned value updated by the correction value from the initial target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation. On the other hand, in the fifth embodiment, the correction value calculated when the air-fuel ratio difference is smaller than zero (i.e. when the detected air-fuel ratio is larger than the estimated ratio) is calculated as a suitable negative value such that the detected air-fuel ratio does not become smaller than the estimated ratio when the fuel injection amount obtained by subtracting the learned value updated by the correction value from the target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation.

[0197] By using as the target fuel injection amount for the fuel injector opening time calculation, the fuel injection amount obtained by subtracting the learned value updated as explained above from the initial target fuel injection amount, the air-fuel ratio difference becomes small and eventually becomes zero. Next, the reason thereof will be explained. Below, for facilitating the understanding, the reason will be explained assuming that the initial target fuel injection amount and the engine speed do not change.

[0198] In the fifth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment and therefore, when the detected air-fuel ratio is smaller than the estimated ratio (i.e. when the detected air-fuel ratio is richer than the estimated ratio), the positive correction value is calculated. Then, this calculated value is added to the learned value KG of the map of Fig.20 corresponding to the current amount Q (the initial target fuel injection amount TQ is used as this amount Q) and the current speed N. The correction value is positive and therefore, the learned value KG becomes large. Then, the fuel injection amount obtained by subtracting the learned value KG from the initial target fuel injection amount TQ is used as the target fuel injection amount for the fuel injector opening time calculation and therefore, the target fuel injection amount for this calculation becomes small. As a result, the fuel injection amount becomes small. Therefore, the detected air-fuel ratio becomes large.

[0199] On the other hand, in the fifth embodiment, the initial target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the initial amount TQ does not change and therefore, the estimated air-fuel ratio does not change.

[0200] As explained above, when the detected air-fuel ratio is smaller than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes large and the estimated air-fuel ratio does not change and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is smaller than the estimated ratio (i.e. as far as the air-fuel ratio difference is larger than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues

to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0201] On the other hand, when the detected air-fuel ratio is larger than the estimated ratio (i.e. when the detected air-fuel ratio is leaner than the estimated ratio), the negative correction value is calculated. Then, this calculated correction value is added to the learned value KG of the map of Fig.20 corresponding to the current amount Q (the initial target fuel injection amount TQ is used as this amount Q) and the current speed N. The correction value is negative and therefore, the learned value KG becomes small. Then, the fuel injection amount obtained by subtracting the learned value KG from the initial target fuel injection amount TQ is used as the target fuel injection amount for the fuel injector opening time calculation and therefore, the target fuel injection amount for this calculation becomes large. As a result, the fuel injection amount becomes large. Therefore, the detected air-fuel ratio becomes small.

[0202] On the other hand, in the fifth embodiment, the initial target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio calculation and the initial amount TQ does not change and therefore, the estimated air-fuel ratio does not change.

[0203] As explained above, when the detected air-fuel ratio is larger than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes small and the estimated air-fuel ratio does not change and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is larger than the estimated ratio (i.e. as far as the air-fuel ratio difference is smaller than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0204] As explained relating to the first embodiment, in the case that the learned value becomes large excessively, the initial target fuel injection amount is corrected excessively by the learned value and as a result, the target fuel injection amount for the fuel injector opening time calculation is corrected excessively, however, this is not preferred.

[0205] In the fifth embodiment, for avoiding the excessive correction of the target fuel injection amount for the fuel injector opening time calculation, a value suitable as the upper limit of the learned value (this is positive and hereinafter, will be referred to as -- upper limit learned value--) and a value suitable as the lower limit of the learned value (this is negative and hereinafter, will be referred to as --lower limit learned value--) are set. Then, when the learned value corrected by the correction value is positive and is larger than the upper limit learned value, the learned value is limited to the upper limit learned value. On the other hand, when the learned value corrected by the correction value is negative and is smaller than the lower limit learned value (i.e. when the absolute value of the learned value is larger than that of the lower limit learned value, since the learned value and the lower limit

learned value are negative), the learned value is limited to the lower limit learned value.

[0206] The setting of the upper and lower limit learned values of the fifth embodiment is performed according to the same process as that of the first embodiment. However, when the maximum fuel injection amount increase difference occurs, the maximum learned value due to the fuel injection amount difference of the fifth embodiment is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease difference occurs, the minimum learned value due to the fuel injection amount difference is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount and the fuel pressure. Further, when the maximum intake air amount increase difference occurs, the maximum learned value due to the intake air amount difference is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount. Further, when the maximum intake air amount decrease difference occurs, the minimum learned value due to the intake air amount difference is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount.

[0207] The setting of the upper and lower limit learned values of the fifth embodiment may be performed according to the same process as that of the second embodiment. However, when the maximum fuel injection amount increase and intake air amount increase differences occur, the maximum learned value is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease and intake air amount decrease differences occur, the minimum learned value is a value obtained eventually by the update according to the fifth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount, the fuel pressure and the intake air amount.

[0208] Next, an example of the routine for performing the control of the fuel injector of the fifth embodiment will be explained. This example of the routine is shown in Fig. 21. The routine of Fig. 21 is performed every a predetermined time has elapsed.

[0209] When the routine of Fig.21 starts, first, at step 60, the accelerator pedal Dac and the engine speed N are acquired. Next, at step 61, the target fuel injection amount TQ is acquired from the map of Fig.2(A) on the basis of the degree Dac acquired at step 60. Next, at step 62, among the learned values KG memorized in the unit 60, the learned value KG corresponding to the target

amount TQ acquired at step 61 and the speed N acquired at step 60 is acquired. Next, at step 63, the target amount TQ acquired at step 61 is corrected by subtracting the value KG acquired at step 62 from the target amount TQ acquired at step 61. Next, at step 64, the fuel injector opening time TO for injecting the fuel of the target amount TQ corrected at step 63 from the injector is calculated. Next, at step 65, the command value for opening the injector for the time TO calculated at step 64 is output to the fuel injector and then, the routine is terminated.

[0210] The control of the throttle valve of the fifth embodiment is, for example, performed by the routine of Fig. 6. However, in the case that the routine of Fig.6 is used for the control of the throttle valve of the fifth embodiment, the fuel injection amount Q acquired at step 20 is the target fuel injection amount TQ acquired at step 61 of Fig.21.

[0211] Next, an example of the routine for performing the control of the EGR control valve of the fifth embodiment will be explained. This example of the routine is shown in Fig. 22. The routine of Fig. 22 is performed every a predetermined time has elapsed.

[0212] When the routine of Fig.22 starts, first, at step 70, the fuel injection amount Q and the engine speed N are acquired. The amount Q acquired at step 70 is the target amount TQ acquired at step 61 of Fig.21. Next, at step 71, the target EGR rate TRegr is acquired from the map of Fig.2(C) on the basis of the amount Q and the speed N acquired at step 70. Next, at step 72, the command value for accomplishing the target rate TRegr acquired at step 71 is output to the EGR control valve and then, the routine is terminated.

[0213] The update of the learned value of the fifth embodiment is, for example, performed by the routine of Fig. 8 or 10. However, in the case that the routine of Fig.8 is used for the update of the learned value of the fifth embodiment, the learned value KG acquired at step 101 is the learned value of the map of Fig.20 corresponding to the amount Q and the speed N acquired at step 100, the maximum and minimum learned values MaxF and MinF acquired at step 101 of Fig.8 are the above-explained maximum and minimum learned value due to the fuel injection amount difference of the fifth embodiment, respectively and the maximum and minimum learned values MaxA and MinA acquired at step 101 of Fig.8 are the above-explained maximum and minimum learned values due to the intake air amount difference of the fifth embodiment, respectively. Further, in the case that the routine of Fig.10 is used for the update of the learned value of the fifth embodiment, the learned value KG acquired at step 201 of Fig. 10 is the learned value of the map of Fig.20 corresponding to the amount Q and the speed N acquired at step 200 and the maximum and minimum learned values Max and Min acquired at step 201 of Fig.10 are the above-explained maximum and minimum learned values of the fifth embodiment, respectively.

[0214] The fifth embodiment is one in the case that the

invention is applied to the control device which corrects only the target fuel injection amount for the fuel injector opening time calculation by the learned value. However, the invention can be applied to the control device which corrects the fuel injection amount for the estimated air-fuel ratio calculation as well as the target fuel injection amount for the fuel injector opening time calculation by the learned value. Next, the embodiment in the case that the invention is applied to such a control device (hereinafter, this embodiment will be referred to as-- sixth embodiment--) will be explained. The engine of the sixth embodiment is the above- explained engine shown in Fig. 1 and therefore, the explanation of the constitution thereof will be omitted.

[0215] First, the control of the fuel injector of the sixth embodiment will be explained. In the sixth embodiment, as shown in Fig. 23, the learned values KG are memorized in the unit 60 in the form of a map as a function of the fuel injection amount Q and the engine speed N.

[0216] Then, in the sixth embodiment, during the engine operation, the target amount TQ is acquired from the map of Fig. 2 (A) on the basis of the accelerator pedal opening degree Dac. Then, the learned value KG corresponding to the amount Q (the target fuel injection amount TQ is used as this amount Q) and the engine speed N is acquired from the map of Fig. 23. Then, the fuel injection amount obtained by subtracting the learned value KG from the acquired target amount (hereinafter, this amount will be referred to as initial target fuel injection amount--) TQ is set as the target fuel injection amount for the fuel injector opening time calculation. Then, the fuel injector opening time necessary to inject the fuel of the set target fuel injection amount for the fuel injector opening time calculation from the injector is calculated on the basis of the target fuel injection amount. Then, the opening time of the injector is controlled at each intake stroke such that the injector opens for the calculated fuel injector opening time.

[0217] The controls of the opening degrees of the throttle valve and the EGR control valve of the sixth embodiment are the same as those of the fifth embodiment and therefore, the explanation thereof will be omitted.

[0218] Further, in the sixth embodiment, the fuel injection amount obtained by adding the learned value to the initial target fuel injection amount TQ (i.e. the target amount TQ acquired from the map of Fig. 2 (A)) is used as the fuel injection amount for the estimated air- fuel ratio calculation.

[0219] Further, in the sixth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment. However, in the sixth embodiment, the correction value calculated when the air- fuel ratio difference is larger than zero (i.e. when the detected air- fuel ratio is smaller than the estimated ratio) is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated ratio when the fuel injection amount obtained

by subtracting the learned value updated by the correction value from the initial target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation and the fuel injection amount obtained by adding the learned value updated by the correction value is used as the fuel injection amount for the estimated air- fuel ratio calculation. On the other hand, in the sixth embodiment, the correction value calculated when the air- fuel ratio difference is smaller than zero (i.e. when the detected air- fuel ratio is larger than the estimated ratio) is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated ratio when the fuel injection amount obtained by subtracting the learned value updated by the correction value from the initial target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation and the fuel injection amount obtained by adding the learned value updated by the correction value to the initial target fuel injection amount is used as the fuel injection amount for the estimated air- fuel ratio calculation.

[0220] By using as the target fuel injection amount for the fuel injector opening time calculation, the fuel injection amount obtained by subtracting the learned value updated as explained above from the initial target fuel injection amount and by using as the fuel injection amount for the estimated air-fuel ratio calculation, the fuel injection amount obtained by adding the learned value to the initial target fuel injection amount, the air-fuel ratio difference becomes small and eventually becomes zero. Next, the reason thereof will be explained. Below, for facilitating the understanding, the reason will be explained assuming that the initial target fuel injection amount and the engine speed do not change.

[0221] In the sixth embodiment, the update of the learned value and the calculation of the correction value are performed according to the same processes as those of the first embodiment and therefore, when the detected air-fuel ratio is smaller than the estimated ratio (i.e. when the detected air-fuel ratio is richer than the estimated ratio), the positive correction value is calculated. Then, this calculated correction value is added to the learned value KG of the map of Fig.23 corresponding to the current amount Q (the initial target fuel injection amount TQ is used as this amount Q) and the current speed N. The correction value is positive and therefore, the learned value KG becomes large. Then, the fuel injection amount obtained by subtracting the learned value KG from the initial target fuel injection amount TQ is used as the target fuel injection amount for the fuel injector opening time calculation and therefore, the target fuel injection amount for this calculation becomes small. As a result, the fuel injection amount becomes small. Therefore, the detected air-fuel ratio becomes large.

[0222] On the other hand, in the sixth embodiment, the fuel injection amount obtained by adding the learned value to the initial target fuel injection amount TQ is used as the fuel injection amount for the estimated air-fuel ratio

calculation and the learned value KG is increased by the correction value and therefore, the estimated air-fuel ratio becomes small.

[0223] As explained above, when the detected air-fuel ratio is smaller than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes large and the estimated air-fuel ratio becomes small and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is smaller than the estimated ratio (i.e. as far as the air-fuel ratio difference is larger than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0224] On the other hand, when the detected air-fuel ratio is larger than the estimated ratio (i.e. when the detected air-fuel ratio is leaner than the estimated ratio), the negative correction value is calculated. Then, this calculated correction value is added to the learned value KG of the map of Fig.23 corresponding to the current amount Q (the initial target fuel injection amount TQ is used as this amount Q) and the current speed N. The correction value is negative and therefore, the learned value KG becomes small. Then, the fuel injection amount obtained by subtracting the learned value KG from the initial target fuel injection amount TQ is used as the target fuel injection amount for the fuel injector opening time calculation and therefore, the target fuel injection amount for this calculation becomes large. As a result, the fuel injection amount becomes large. Therefore, the detected air-fuel ratio becomes small.

[0225] On the other hand, in the sixth embodiment, the fuel injection amount obtained by adding the learned value to the initial target fuel injection amount is used as the fuel injection amount for the estimated air-fuel ratio calculation and the learned value KG is decreased by the learned value KG and therefore, the estimated air-fuel ratio becomes large.

[0226] As explained above, when the detected air-fuel ratio is larger than the estimated ratio, by the update of the learned value, the detected air-fuel ratio becomes small and the estimated air-fuel ratio becomes large and therefore, the air-fuel ratio difference becomes small. As far as the detected air-fuel ratio is larger than the estimated ratio (i.e. as far as the air-fuel ratio difference is smaller than zero), the update of the learned value is performed repeatedly (i.e. the learned value continues to become large). Thus, the air-fuel ratio difference becomes zero eventually.

[0227] As explained relating to the first embodiment, in the case that the learned value becomes large excessively, the initial target fuel injection amount is corrected excessively by the learned value and as a result, the target fuel injection amount for the fuel injector opening time calculation and the fuel injection amount for the estimated air-fuel ratio calculation are corrected excessively, however, this is not preferred.

[0228] In the sixth embodiment, for avoiding the ex-

cessive correction of the target fuel injection amount for the fuel injector opening time calculation and the fuel injection amount for the estimated air-fuel ratio calculation, a value suitable as the upper limit of the learned value (this value is positive and hereinafter, will be referred to as --upper limit learned value--) and a value suitable as the lower limit of the learned value (this value is negative and hereinafter, this value will be referred to as --lower limit learned value--) are set. When the learned value corrected by the correction value is positive and is larger than the upper limit learned value, the learned value is limited to the upper limit learned value. On the other hand, when the learned value corrected by the correction value is negative and is smaller than the lower limit learned value (i.e. when the absolute value of the learned value is larger than that of the lower limit learned value, since the learned value and the lower limit learned value are negative), the learned value is limited to the lower limit learned value.

[0229] The setting of the upper and lower limit learned values of the sixth embodiment are performed according to the same processes as those of the first embodiment. However, when the maximum fuel injection amount increase difference occurs, the maximum learned value due to the fuel injection amount difference is a value obtained eventually by the update according to the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount and the fuel pressure. Further, when the maximum fuel injection amount decrease difference occurs, the minimum learned value due to the fuel injection amount difference is a value obtained eventually by the update according to the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount and the fuel pressure. Further, when the maximum intake air amount increase difference occurs, the maximum learned value due to the intake air amount difference is a value obtained eventually by the update according to the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount. Further, when the maximum intake air amount decrease difference occurs, the minimum learned value due to the intake air amount difference is a value obtained eventually by the update according to the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the intake air amount.

[0230] The setting of the upper and lower limit learned values of the sixth embodiment may be performed according to the same process as that of the second embodiment. However, when the maximum fuel injection amount increase and intake air amount increase differences occur, the maximum learned value is a value calculated and updated by the correction value calculated within the specific constraint of the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount, the fuel pressure and the intake air amount. Further, when the

maximum fuel injection amount decrease and intake air amount decrease differences occur, the minimum learned value is a value calculated and updated by the correction value calculated within the specific constraint of the sixth embodiment and is memorized in the unit 60 in the form of a map as a function of the initial target fuel injection amount, the fuel pressure and the intake air amount.

[0231] In the sixth embodiment, one learned value is used as the learned value to be subtracted from the initial target fuel injection amount for calculating the target fuel injection amount for the fuel injector opening time calculation and as the learned value to be added to the initial target fuel injection amount for calculating the fuel injection amount for the estimated air-fuel ratio calculation. That is, the learned value subtracted from the initial target fuel injection amount for calculating the target fuel injection amount for the fuel injector opening time calculation and the learned value added to the initial target fuel injection amount for calculating the fuel injection amount for the estimated air-fuel ratio calculation are the same as each other. However, these learned values may be different from each other. In this case, the upper and lower limit learned values regarding each learned value are set similar to the first embodiment.

[0232] The control of the fuel injector of the sixth embodiment is, for example, performed by the routine of Fig. 21. However, in the case that the routine of Fig. 21 is used for the control of the fuel injector of the sixth embodiment, the learned value KG acquired at step 62 is a value obtained eventually by the update according to the sixth embodiment.

[0233] The control of the throttle valve of the sixth embodiment is, for example, performed by the routine of Fig. 6. However, in the case that the routine of Fig. 6 is used for the control of the throttle valve of the sixth embodiment, the fuel injection amount Q acquired at step 20 is the target fuel injection amount TQ acquired at step 61 of Fig. 21.

[0234] The control of the EGR control valve of the sixth embodiment is, for example, performed by the routine of Fig. 22.

[0235] The update of the learned value of the sixth embodiment is, for example, performed by the routine of Fig. 8 or 10. However, in the case that the routine of Fig. 8 is used for the update of the learned value of the sixth embodiment, the learned value KG acquired at step 10 is the learned value of the map of Fig. 23 corresponding to the amount Q and the speed N acquired at step 100, the maximum and minimum learned values MaxF and MinF acquired at step 101 of Fig. 8 are the above-explained maximum and minimum learned values due to the fuel injection amount difference of the sixth embodiment, respectively and the maximum and minimum learned values MaxA and MinA acquired at step 101 of Fig. 8 are the above-explained maximum and minimum values due to the intake air amount difference of the sixth embodiment, respectively. Further, in the case that the routine

of Fig. 10 is used for the update of the learned value of the sixth embodiment, the learned value KG acquired at step 201 is the learned value of the map of Fig. 23 corresponding to the amount Q and the speed N acquired at step 200 and the maximum and minimum learned values Max and Min acquired at step 201 of Fig. 10 are the above-explained maximum and minimum learned values of the sixth embodiment, respectively.

[0236] According to the above-explained embodiments, before the learned value is added to or subtracted from the target fuel injection amount (i.e. before the target fuel injection amount is corrected by the learned value), the learned value is newly calculated. That is, the learned value is updated to the latest learned value. Therefore, the latest learned value is added to or subtracted from the target fuel injection amount. Further, immediately before the learned value is added to or subtracted from the target fuel injection amount (i.e. immediately before the target fuel injection amount is corrected by the learned value), the latest learned value is calculated and therefore, the optimum learned value at that time is added to or subtracted from the target fuel injection amount. Thus, the unsuitable correction of the target fuel injection amount is avoided and therefore, the detected air-fuel ratio corresponds to the estimated ratio exactly.

[0237] Further, according to the embodiment where the routine of Fig. 8 of the above-explained embodiments is used, in order to correct the intake air amount or the fuel injection amount to the maximum extent possible as far as the requirements of the engine are accomplished, the more suitable upper and lower limit learned values are set. That is, in general, it is preferred that the intake air amount or the fuel injection amount is corrected to the maximum extent possible as far as the requirements of the engine are accomplished. On the other hand, the various controls in the engine are established such that the requirements of the engine are accomplished even in the case that it is expected that the fuel injection amount difference amount becomes large to the maximum extent when the actual fuel injection amount differs positively from the target fuel injection amount, even in the case that it is expected that the fuel injection amount difference amount becomes large to the maximum extent when the actual fuel injection amount differs negatively from the target fuel injection amount, even in the case that it is expected that the intake air amount difference amount becomes large to the maximum extent when the detected intake air amount differs positively from the actual intake air amount and even in the case that it is expected that the detected intake air amount differs negatively from the actual intake air amount. That is, the learned value in the case that the fuel injection amount difference is largest among the possible differences (i.e. the maximum and minimum learned values due to the fuel injection amount difference) and the learned value in the case that the intake air amount difference is largest among the possible differences (i.e. the maximum and minimum learned values due to the intake air amount difference) are com-

pared with each other, the larger maximum learned value among the maximum learned values is set as the upper limit learned value and the smaller minimum value among the minimum learned value is set as the lower limit learned value and if the learned value is limited to the upper and lower limit learned values, the learned value which corrects the intake air amount or the fuel injection amount to the maximum extent while accomplishing the requirements of the engine can be obtained. Therefore, in order to correct the intake air amount or the fuel injection amount to the maximum extent possible as far as the requirements of the engine are accomplished, the more suitable upper and lower limit learned values are set.

[0238] Further, according to the embodiment where the routine of Fig. 10 of the above- explained embodiments is used, in order to correct the intake air amount or the fuel injection amount to the maximum extent possible as far as the requirements of the engine are accomplished, the more suitable upper and lower limit learned values are set. That is, in general, it is preferred that the intake air amount or the fuel injection amount is corrected to the maximum extent possible as far as the requirements of the engine are accomplished. On the other hand, the various controls in the engine are established such that the requirements of the engine are accomplished even in the case that it is expected that the fuel injection amount difference amount becomes large to the maximum extent when the actual fuel injection amount differs positively from the target fuel injection amount and the intake air amount difference amount becomes large to the maximum extent when the detected intake air amount differs positively from the actual intake air amount and even in the case that it is expected that the fuel injection amount becomes large to the maximum extent when the actual fuel injection amount differs negatively from the target fuel injection amount and the intake air amount becomes large to the maximum extent when the detected intake air amount differs negatively from the actual intake air amount. That is, the learned value in the case that the fuel injection amount difference is largest among the possible differences and the intake air amount difference is largest among the possible differences is set as the upper or lower limit learned value and if the learned value is limited to the upper or lower limit learned value, the learned value which corrects the intake air amount or the fuel injection amount to the maximum extent while accomplishing the requirements of the engine can be obtained. Therefore, in order to correct the intake air amount or the fuel injection amount to the maximum extent possible as far as the requirements of the engine are accomplished, the more suitable upper or lower limit learned value is set.

[0239] Broadly, the concept of the above- explained embodiments can be applied to the engine wherein the fuel is supplied to the combustion chamber by means other than the fuel injector. Therefore, the invention can be applied to the engine comprising means for supplying

the fuel to the combustion chamber.

[0240] Broadly, the concept of the above- explained embodiments can be applied to the engine wherein the amount of the air supplied to the combustion chamber is detected by means other than the air flow meter. In the above- explained embodiments, the detected intake air amount can be understood as the estimated value of the amount of the air supplied to the combustion chamber. Therefore, the invention can be applied to the engine comprising means for acquiring the estimated value of the amount of the air supplied to the combustion chamber.

[0241] Broadly, the concept of the above- explained embodiments can be applied to the engine where the actual air- fuel ratio is acquired by means other than the oxygen concentration sensor means. Therefore, the invention can be applied to the engine comprising means for acquiring the actual air- fuel ratio.

[0242] Broadly, the concept of the above- explained embodiments can be applied to the engine where the estimated value of the fuel injection amount other than the target fuel injection amount or the parameter corresponding thereto is used for the acquisition of the target EGR rate or the target throttle valve opening degree or the target vane opening degree and the calculation of the estimated air- fuel ratio. The target fuel injection amount can be understood as the estimated value of the amount of the fuel supplied to the combustion chamber (i.e. the estimated supplied fuel amount) . Therefore, the invention can be applied to the engine where the estimated supplied fuel amount or the parameter corresponding thereto is used for the acquisition of the target EGR rate or the target throttle valve opening degree or the target vane opening degree and the calculation of the estimated air- fuel ratio.

[0243] Broadly, the concept of the above- explained embodiments can be applied to the engine where the estimated value of the intake air amount other than the detected intake air amount or the parameter corresponding thereto is used for the calculation of the estimated air- fuel ratio. As explained above, the detected intake air amount can be understood as the estimated value of the amount of the air supplied to the combustion chamber (i.e. the estimated supplied air amount) . Therefore, the invention can be applied to the engine where the estimated supplied air amount or the parameter corresponding thereto is used for the calculation of the estimated air- fuel ratio.

[0244] The first and second embodiments are those in the case that the invention is applied to the case where the target fuel injection amount acquired from the map of Fig.2(A) is corrected by the learned value, the target EGR rate is acquired from the map of Fig.2(C) on the basis of the corrected target fuel injection amount and the engine speed and this acquired target EGR rate is used as the target EGR rate for the EGR rate control. The invention can be applied to the control device where the target EGR rate is acquired from the map of Fig.2(C)

on the basis of the target fuel injection amount acquired from the map of Fig.2(A) and the engine speed, this acquired target EGR rate is corrected by the learned value and this corrected target EGR rate is used as the target EGR rate for the EGR rate control (in particular, for example, the control device where the target EGR rate is corrected by subtracting the learned value from the target EGR rate acquired from the map and this corrected target EGR rate is used as the target EGR rate for the EGR rate control).

[0245] The third embodiment is one in the case that the invention is applied to the case where the target fuel injection amount acquired from the map of Fig.12(A) is corrected by the learned value, the target throttle valve opening degree is acquired from the map of Fig.12(B) on the basis of the corrected target fuel injection and the engine speed and this acquired degree is used as the target throttle valve opening degree for the throttle valve opening degree control. However, the invention can be applied to the control device where the target throttle valve opening degree is acquired from the map of Fig. 12(B) on the basis of the target fuel injection amount acquired from the map of Fig.12(A) and the engine speed, this acquired target throttle valve opening degree is corrected by the learned value and this corrected degree is used as the target throttle valve opening degree for the throttle valve opening degree control (in particular, for example, the control device where the target throttle valve opening degree is corrected by adding the learned value to the target throttle valve opening degree acquired from the map and this corrected degree is used for the target throttle valve opening degree for the throttle valve opening degree control).

[0246] Further, the fourth embodiment is one in the case that the invention is applied to the case where the target fuel injection amount acquired from the map of Fig. 17 (A) is corrected by the learned value, the target vane opening degree is acquired from the map of Fig. 17 (C) on the basis of this corrected target amount and the engine speed and this acquired target vane opening degree is used for the target vane opening degree for the vane opening degree control. However, the invention can be applied to the control device where the target vane opening degree is acquired from the map of Fig. 17 (C) on the basis of the target fuel injection amount acquired from the map of Fig. 17 (A) and the engine speed, this acquired target vane opening degree is corrected by the learned value and this corrected degree is used for the target vane opening degree for the vane opening degree control (in particular, for example, the control device where the target vane opening degree is corrected by subtracting the learned value from the target vane opening degree acquired from the map and this corrected degree is used as the target vane opening degree for the vane opening degree control).

[0247] Further, the first and second embodiment are those in the case that the invention is applied to the case where the target EGR rate is acquired from the map of

Fig. 2 (C) on the basis of the fuel injection amount and the engine speed. However, the invention can be applied to the control device where the target EGR rate is acquired on the basis of only the fuel injection amount or the control device where the target EGR rate is acquired on the basis of three parameter or more including the fuel injection amount and the engine speed or the control device where the target EGR rate is acquired on the basis of one or more parameters other than the fuel injection amount and the engine speed.

[0248] Further, the third embodiment is one in the case that the invention is applied to the case where the target throttle valve opening degree is acquired from the map of Fig. 12 (B) on the basis of the fuel injection amount and the engine speed. However, the invention can be applied to the control device where the target throttle valve opening degree is acquired on the basis of only the fuel injection amount or the control device where the target throttle valve opening degree is acquired on the basis of three or more parameters including the fuel injection amount and the engine speed or the control device where the target throttle valve opening degree is acquired on the basis of one or more parameters other than the fuel injection amount and the engine speed.

[0249] Further, the fourth embodiment is one in the case that the invention is applied to the control device where the target vane opening degree is acquired from the map of Fig. 17 (C) on the basis of the fuel injection amount and the engine speed. However, the invention can be applied to the control device where the target vane opening degree is acquired on the basis of only the fuel injection amount or the control device where the target vane opening degree is acquired on the basis of three or more parameters including the fuel injection amount and the engine speed or the control device where the target vane opening degree is acquired on the basis of one or more parameters other than the fuel injection amount and the engine speed.

[0250] Further, the above-explained embodiments are those in the case that the invention is applied to the control device where only the target fuel injection is corrected by the learned value in order to obtain the fuel injection amount for the acquisition of the target value (i.e. the target EGR rate or throttle valve opening degree or vane opening degree). However, the invention can be applied to the control device where only the engine speed is corrected by the learned value in order to obtain the engine speed for the acquisition of the target value or the control device where both of the target fuel injection amount and the engine speed are corrected by the learned value in order to obtain the fuel injection amount and the engine speed for the acquisition of the target value.

[0251] Further, the above-explained embodiments are those in the case that the fuel injection amount and the engine speed are used for the acquisition of the target value (i.e. the target EGR rate or throttle valve opening degree or vane opening degree). However, the invention can be applied to the control device where three or more

parameters including the fuel injection amount and the engine speed are used for the acquisition of the target value or the control device where one or more parameters other than the fuel injection amount and the engine speed are used for the acquisition of the target value. In the case that the invention is applied to such control devices, at least one parameter is corrected by the learned value and this corrected parameter is used for the acquisition of the target value.

[0252] In the first and second embodiments, the EGR rate is corrected on the basis of the air-fuel ratio difference. Therefore, in these embodiments, it can be understood that the EGR gas amount is corrected on the basis of the air-fuel ratio difference.

[0253] The embodiments using the routine of Fig. 8 among the above-explained embodiments are those in the case that the invention is applied to the control device where the maximum and minimum learned values due to the fuel injection amount difference are acquired depending on the fuel injection amount and the fuel pressure. However, the invention can be applied to the control device where the maximum and minimum learned values are acquired depending on only the fuel injection amount.

[0254] Further, in the first and second embodiments, the EGR rate is corrected by the learned value. When the EGR rate is corrected, the intake air amount changes and therefore, it can be understood that the intake air amount is corrected by the learned value.

[0255] In the above-explained embodiments, the estimated air-fuel ratio is calculated on the basis of the detected intake air amount and the target fuel injection amount at a particular timing. However, a certain time is necessary until the exhaust gas reaches the oxygen concentration sensor after the mixture gas of the air of the detected intake air amount at the particular timing and the fuel of the target fuel injection amount at the particular timing burns and the combustion gas is discharged as the exhaust gas from the combustion chamber. In the above-explained embodiments, the air-fuel ratio may be calculated by subtracting the detected air-fuel ratio from the estimated air-fuel ratio which is first-order-smoothed.

[0256] The maximum and minimum learned values due to the fuel injection amount difference may be obtained by a method other than those of the above-explained embodiments. As such a method, for example, a method for acquiring the sufficient number of the learned values calculated in the case that the fuel injection amount difference in which the actual fuel injection amount differs from the target fuel injection amount (i.e. this fuel injection amount difference includes the fuel injection amount difference in which the actual injection amount becomes larger than the target fuel injection amount and the fuel injection amount difference in which the actual fuel injection amount becomes smaller than the target fuel injection amount) occurs and processing these acquired learned values by a statistical method to obtain a value suitable as the maximum learned value due to the fuel injection amount difference and a value

suitable as the minimum learned value due to the fuel injection amount difference as the maximum and minimum learned values due to the fuel injection amount difference, respectively can be employed.

[0257] Similarly, the maximum and minimum learned values due to the intake air amount difference may be obtained by a method other than those of the above-explained embodiments. As such a method, for example, a method for acquiring the sufficient number of the learned values calculated in the case that the intake air amount difference in which the detected intake air amount differs from the actual intake air amount (i.e. this intake air amount difference includes the intake air amount difference in which the detected intake air amount becomes larger than the actual intake air amount and the intake air amount difference in which the detected intake air amount becomes smaller than the actual intake air amount) occurs and processing these acquired learned values by a statistical method to obtain a value suitable as the maximum learned value due to the intake air amount difference and a value suitable as the minimum learned value due to the intake air amount difference as the maximum and minimum learned values due to the intake air amount difference, respectively can be employed.

[0258] Further, in the above-explained embodiments using the routine of Fig. 8, as the maximum fuel injection amount increase and decrease differences, the drawings tolerance (i.e. the nominal error) of the fuel injector regarding the fuel injection amount may be used. That is, in the case that the actual fuel injection amount becomes larger than the target fuel injection amount to the maximum extent within the drawings tolerance of the fuel injector, the eventually-obtained learned value may be set as the maximum learned value due to the fuel injection amount difference and in the case that the actual fuel injection amount becomes smaller than the target fuel injection amount to the maximum extent within the drawings tolerance of the fuel injector, the eventually-obtained learned value may be set as the minimum learned value due to the fuel injection amount difference.

[0259] Similarly, in the above-mentioned embodiments using the routine of Fig. 8, as the maximum intake air amount increase and decrease differences, the drawings tolerance (i.e. the nominal error) of the air flow meter regarding the detected intake air amount may be used. That is, in the case that the detected intake air amount becomes larger than the actual intake air to the maximum extent within the drawings tolerance of the air flow meter, the eventually-obtained learned value may be set as the maximum learned value due to the intake air amount difference and in the case that the detected intake air amount becomes smaller than the actual intake air amount to the maximum extent within the drawings tolerance of the air flow meter, the eventually-obtained learned value may be set as the minimum learned value due to the intake air difference.

[0260] Further, in the above-explained embodiments

using the routine of Fig. 10, as the maximum fuel injection amount increase and decrease differences, the drawings tolerance (i.e. the nominal error) of the fuel injector regarding the fuel injection amount may be used and as the maximum intake air amount increase and decrease differences, the drawings tolerance (i.e. the nominal error) of the air flow meter regarding the detected intake air amount may be used. That is, in the case that the actual fuel injection amount becomes larger than the target fuel injection amount to the maximum extent within the drawings tolerance of the fuel injector and the detected intake air amount is larger than the actual intake air amount to the maximum extent within the drawings tolerance of the air flow meter, the eventually- obtained learned value may be set as the maximum learned value and in the case that the actual fuel injection amount becomes smaller than the target fuel injection amount to the maximum extent within the drawings tolerance of the fuel injector and the detected intake air amount becomes smaller than the actual intake air amount to the maximum extent within the drawings tolerance of the air flow meter, the eventually- obtained learned value may be set as the minimum learned value.

[0261] The invention can be applied to the control device using the fuel injection amount obtained by adding the learned value to the target fuel injection amount as the fuel injection amounts for the target EGR rate acquisition, the target throttle valve opening degree acquisition and the estimated air-fuel ratio calculation. That is, the concept of the third embodiment may be combined with the concept of the first or second embodiment. In this case, the correction value calculated when the air-fuel ratio difference is larger than zero is a suitable positive value such that the detected air fuel ratio does not become larger than the estimated air-fuel ratio when the control of the engine using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air-fuel ratio difference is smaller than zero is a suitable negative value such that the detected air-fuel ratio does not become smaller than the estimated air-fuel ratio when the control of the engine using the learned value updated by the correction value is performed.

[0262] In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value eventually obtained when the update of the learned value and the control of the engine using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value similarly eventually obtained in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the

minimum learned value due to the fuel injection amount is a value eventually obtained when the update of the learned value and the control of the engine using the learned value are repeatedly performed in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake air amount difference is a value similarly eventually obtained in the case that the maximum intake air amount decrease difference occurs.

[0263] Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the control of the engine using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0264] Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target EGR rate acquisition, the target vane opening degree acquisition and the estimated air- fuel ratio calculation. That is, the concept of the fourth embodiment may be combined with that of the first or second embodiment. In this case, the correction value calculated when the air-fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air-fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

[0265] In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the minimum learned value due to the fuel injection amount difference is a value obtained eventually when the update

of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount decrease difference occurs.

[0266] Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0267] Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target EGR rate acquisition and the estimated air- fuel ratio calculation and the fuel injection amount obtained by subtracting the learned value from the target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation. That is, the concept of the fifth or sixth embodiment may be combined with that of the first or second embodiment. In this case, the correction value calculated when the air- fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air- fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

[0268] In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the minimum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are

performed repeatedly in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake air amount difference is a value obtained similarly in the case that the maximum intake air amount decrease difference occurs.

[0269] Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0270] Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target throttle valve opening degree acquisition, the target vane opening degree acquisition and the estimated air- fuel ratio calculation. That is, the concepts of the third and fourth embodiments may be combined with the concept of the first or second embodiment. In this case, the correction value calculated when the air- fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air- fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

[0271] In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the minimum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake

air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount decrease difference occurs.

[0272] Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0273] Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target EGR rate acquisition, the target throttle valve opening degree acquisition and the estimated air- fuel ratio calculation and the fuel injection amount obtained by subtracting the learned value from the target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation. That is, the concept of the fifth or sixth embodiment may be combined with that of the first or second embodiment. In this case, the correction value calculated when the air- fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air- fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

[0274] In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the minimum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount decrease difference

occurs and the minimum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount decrease difference occurs.

5 **[0275]** Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

10 **[0276]** Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target EGR rate acquisition, the target vane opening degree acquisition and the estimated air- fuel ratio calculation and the fuel injection amount obtained by subtracting the learned value from the target fuel injection amount is used as the target fuel injection amount for the the fuel injector opening time calculation. That is, the concepts of the fourth embodiment and the fifth or sixth embodiment may be combined with the concept of the first or second embodiment. In this case, the correction value calculated when the air- fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air- fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

30 **[0277]** In this case, if the maximum learned values due to the fuel injection amount and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the minimum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the

learned value are performed repeatedly in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount decrease difference occurs.

[0278] Further, if the maximum and minimum learned values are set as the upper and lower limit learned values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually similarly in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0279] Further, this invention can be applied to the control device in which the fuel injection amount obtained by adding the learned value to the target fuel injection amount is used as the fuel injection amounts for the target EGR rate acquisition, the target throttle valve opening degree acquisition, the target vane opening degree acquisition and the estimated air- fuel ratio calculation and the fuel injection amount obtained by subtracting the learned value from the target fuel injection amount is used as the target fuel injection amount for the fuel injector opening time calculation. That is, the concepts of the third and fourth embodiments and the fifth or sixth embodiment may be combined with the concept of the first or second embodiment. In this case, the correction value calculated when the air- fuel ratio difference is larger than zero is calculated as a suitable positive value such that the detected air- fuel ratio does not become larger than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed. On the other hand, the correction value calculated when the air- fuel ratio difference is smaller than zero is calculated as a suitable negative value such that the detected air- fuel ratio does not become smaller than the estimated air- fuel ratio when the engine control using the learned value updated by the correction value is performed.

[0280] In this case, if the maximum learned values due to the fuel injection and intake air amount differences are used for setting the upper limit learned value as in the first embodiment, the maximum learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount increase difference occurs and the maximum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount increase difference occurs. Further, if the minimum learned values due to the fuel injection amount and intake air amount differences are used for setting the lower limit learned value, the mini-

um learned value due to the fuel injection amount difference is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount decrease difference occurs and the minimum learned value due to the intake air amount difference is a value obtained eventually similarly in the case that the maximum intake air amount decrease difference occurs.

[0281] Further, if the maximum and minimum learned values are set as the upper and lower limit values, respectively as in the second embodiment, the maximum learned value is a value obtained eventually when the update of the learned value and the engine control using the learned value are performed repeatedly in the case that the maximum fuel injection amount and intake air amount increase differences occur and the minimum learned value is a value obtained eventually in the case that the maximum fuel injection amount and intake air amount decrease differences occur.

[0282] Further, in the case that the addition of the learned value to the target fuel injection amount or the subtraction of the learned value from the target fuel injection amount is understood as the correction of the target fuel injection amount by the correction value, the above- explained embodiment is one obtained by applying this invention to the control device in which the learned value itself is used as the correction value for correcting the target fuel injection amount. However, this invention can be applied to the control device in which in place of the learned value itself, a value calculated on the basis of the learned value is used as the correction value for correcting the target fuel injection amount.

[0283] Further, in the above- explained embodiments, the engine control is performed while the correction value is calculated on the basis of the air- fuel ratio difference, then the learned value is updated by adding the calculated correction value to the learned value corresponding to the current fuel injection amount and the current engine speed and then, this updated learned value is added to or subtracted from the target fuel injection amount, but the calculated correction value and the learned value corresponding to the current fuel injection amount and the current engine speed are added to or subtracted from the target fuel injection amount. That is, in the case that the acquisition of the learned value to be added to or subtracted from the target fuel injection amount is understood as the setting of the correction value for correcting the target fuel injection amount, in the above- explained embodiments, it can be understood that the learned value is updated (i.e. calculated) immediately before the correction value for correcting the target fuel injection amount is set and the correction value for correcting the target fuel injection amount is set by using this updated learned value.

[0284] In consideration of the above-explained matter, it can be broadly understood that the control device introduced from the above-explained embodiment com-

prises fuel supply means (for example, the fuel injector) and air supply means (for example, the intake passage) and controls the air-fuel ratio of the mixture gas by controlling the supplied fuel and air amounts, the learned value used for setting a supplied fuel or air amount correction value which is a correction value for correcting the supplied fuel or air amount (in the above-explained embodiments, the learned value itself is used as the supplied fuel or air amount correction value) being calculated on the basis of the difference (for example, the air-fuel ratio difference) of the actual air-fuel ratio (for example, the detected air-fuel ratio) relative to the target air-fuel ratio (for example, the estimated air-fuel ratio) as a value for decreasing the difference of the air-fuel ratio and the supplied fuel or air amount correction value being set by using the learned value, wherein the learned value is calculated immediately before the setting of the supplied fuel or air amount correction value and the supplied fuel or air amount correction value is set by using the calculated learned value.

[0285] Further, in the case that the acquisition of the learned value to be added to or subtracted from the target fuel injection amount is understood as the setting of the correction value for correcting the target fuel injection amount, in the above-explained embodiments, it can be understood that when the performance of the setting of the correction value for correcting the target fuel injection amount is determined, the updated (i.e. the calculation) of the learned value is performed and the setting of the correction value for correcting the target fuel injection amount is performed according to the above-mentioned determination after the update of this learned value is completed.

[0286] Further, the above- explained embodiment is one obtained by applying this invention to the control device in which the update and usage of the learned value are performed sequentially. However, this invention can be applied to the control device in which the update and usage of the learned value are performed separately. In this case, it is preferred that the update (i.e. the calculation) of the learned value is performed every a predetermined time has elapsed while the usage of the learned value is performed every the predetermined time has elapsed and the performance timings of the usage and the update of the learned value are set such that the period between the performance timing of the usage of the learned value and the performance timing of the update of the learned value immediately before the usage is shorter than that between the performance timing of the usage of the learned value and the performance timing of the update of the learned value immediately after the usage. That is, in the case that the acquisition of the learned value to be added to or subtracted from the target fuel injection amount is understood as the setting of the correction for correcting the target fuel injection amount, it is preferred that the update (i.e. the calculation) of the learned value is performed every a predetermined time has elapsed while the setting of the correction value for

correcting the target fuel injection amount is performed every the predetermined time has elapsed and the performance timings of the setting of the correction value and the update of the learned value are set such that the period between the performance timing of the setting of the correction value and the performance timing of the update of the learned value immediately before the setting is shorter than that between the performance timing of the setting of the correction value and the performance timing of the update of the learned value immediately after the setting.

[0287] Further, in consideration of the above- explained matter, it can be broadly understood that the control device introduced from the above- explained embodiment comprises;

means for acquiring an estimated value of a supplied fuel amount as an estimated supplied fuel amount (in the above- explained embodiments, the fuel injection amount acquired by adding the learned value to the target fuel injection amount),

means for acquiring an estimated value of a supplied air amount as an estimated supplied air amount (in the above- explained embodiments, the detected intake air amount),

means for calculating an air- fuel ratio of the mixture gas as an estimated air- fuel ratio on the basis of the estimated supplied fuel and air amounts,

means for acquiring an actual air- fuel ratio of the mixture gas as an actual air- fuel ratio (in the above- explained embodiments, the detected air- fuel ratio),

means for calculating a correction value for correcting the supplied air amount such that an air- fuel ratio difference, which is a difference of the actual air- fuel ratio relative to the estimated air- fuel ratio, becomes small, and

means for integrating the correction values to calculate a learned value of the correction value and memorizing the learned value,

wherein when no air- fuel ratio difference occurs, the supplied air amount is corrected by only the learned value and when the air- fuel ratio difference occurs, the supplied air amount is corrected by the learned and correction values.

[0288] Further, this control device can be understood as the device wherein the learned value is obtained as a maximum lean- side learned value due to the supplied fuel amount difference (in the above- explained embodiments, the maximum learned value due to the fuel injection amount difference) when the air- fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is larger than the estimated supplied fuel amount occurs and this difference is largest among the possible differences under the condition that the estimated supplied air amount corresponds to the actual supplied air amount (in the above- explained embodiments, in the case that the maximum fuel injection amount increase difference occurs),

the learned value is obtained as a maximum rich- side learned value due to the supplied fuel amount difference (in the above- explained embodiments, the minimum learned value due to the fuel injection amount difference) when the air- fuel ratio difference becomes zero in the case that a supplied fuel amount difference in which the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs and this difference is largest among the possible differences under the condition that the estimated supplied air amount corresponds to the actual supplied air amount (in the above- explained embodiments, the maximum fuel injection amount decrease difference occurs),

the learned value is obtained as a maximum lean- side learned value due to the supplied air amount difference (in the above- explained embodiments, the maximum learned value due to the intake air amount difference) when the air- fuel ratio difference becomes zero in the case that a supplied air amount difference in which the estimated supplied air amount is larger than the actual supplied air amount occurs and this difference is largest among the possible differences under the condition that the estimated supplied fuel amount corresponds to the actual supplied fuel amount (in the above- explained embodiments, the maximum intake air amount increase difference occurs),

the learned value is obtained as a maximum rich- side learned value due to the supplied air amount difference (in the above- explained embodiments, the minimum learned value due to the intake air amount difference) when the air- fuel ratio difference becomes zero in the case that a supplied air amount difference in which the estimated supplied air amount is smaller than the actual supplied air amount occurs and this difference is largest among the possible differences under the condition that the estimated supplied fuel amount corresponds to the actual supplied fuel amount (in the above- explained embodiments, the maximum intake air amount decrease difference occurs),

the larger maximum lean- side learned value among the maximum lean- side learned values due to the supplied fuel and air amount differences is set as an upper limit lean- side learned value (in the above- explained embodiments, the upper limit learned value),

the larger maximum rich- side learned value among the maximum rich- side learned values due to the supplied fuel and air amount differences is set as an upper limit rich- side learned value (in the above- explained embodiments, the lower limit learned value),

when the learned value is a value which increases the supplied air amount (in the above- explained embodiments, the learned value is positive) and is larger than the upper limit lean- side learned value, the learned value is limited to the upper limit lean- side learned value, and when the learned value is a value which decreases the supplied air amount (in the above- explained embodiments, the learned value is negative) and is larger than the upper limit rich- side learned value, the learned value

is limited to the upper limit lean- side learned value.

[0289] Otherwise, this control device can be understood as the device wherein the learned value, which is a value obtained when the air- fuel ratio difference becomes zero in the case that the supplied fuel amount difference in which the actual supplied fuel amount is larger than the estimated supplied fuel amount occurs, this fuel supplied amount difference is largest among the possible differences, the supplied air amount difference in which the estimated supplied air amount is larger than the actual supplied air amount occurs and this supplied air amount difference is largest among the possible differences (in the above- explained embodiments, in the case that the maximum fuel injection amount and intake air amount increase differences occur), is set as an upper limit lean- side learned value (in the above- explained embodiments, the upper limit learned value)

the learned value, which is a value obtained when the air- fuel ratio difference becomes zero in the case that the supplied fuel amount difference in which the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs, this supplied fuel amount difference is largest among the possible differences, the supplied air amount difference in which the estimated supplied air amount is smaller than the actual supplied air amount occurs and this supplied air amount difference is largest among the possible differences (in the above- explained embodiments, in the case that the maximum fuel injection amount and the intake air amount decrease differences occur), is set as an upper limit rich- side learned value (in the above- explained embodiments, the lower limit learned value),

when the learned value is a value which increases the supplied air amount (in the above- explained embodiments, when the learned value is positive) and is larger than the upper limit lean- side learned value, the learned value is limited to the upper limit lean- side learned value, and

when the learned value calculated by the learning means is a value which decreases the supplied air amount (in the above- explained embodiments, when the learned value is negative) and is larger than the upper limit rich- side learned value, the learned value is limited to the upper limit rich- side learned value.

Claims

1. A control device of an internal combustion engine comprising:

fuel supply means for supplying a fuel into a combustion chamber; and
means for supplying an air into the combustion chamber,
wherein the device controls an air-fuel ratio of a mixture gas of the air and the fuel formed in the combustion chamber by controlling a supplied

- fuel amount and a supplied air amount, which fuel amount being an amount of the fuel supplied into the combustion chamber, which air amount being an amount of the air supplied into the combustion chamber,
- wherein the device calculates a learned value used for setting a supplied fuel amount correction value for correcting the supplied fuel amount and a supplied air amount correction value for correcting the supplied air amount as those for decreasing the difference of the air-fuel ratio on the basis of the difference of the actual air-fuel ratio relative to a target air-fuel ratio, and set the supplied fuel and air amount correction values by using the learned value, and
- wherein the device calculates the learned value immediately before the setting of the supplied fuel or air amount correction value and sets the supplied fuel or air amount correction value by using the calculated learned value.
2. The device of Claim 1, wherein in the case that the device sets the supplied fuel amount correction value by using the learned value, the device performs the calculation of the learned value when the device has decided to perform the setting of the supplied fuel amount correction value and then, the device performs the setting of the supplied fuel amount correction value according to the decision after the device completes the calculation of the learned value, and wherein in the case that the device sets the supplied air amount correction value by using the learned value, the device performs the calculation of the learned value when the device has decided to perform the setting of the supplied air amount correction value and then, the device performs the setting of the supplied air amount correction value according to the decision after the device completes the calculation of the learned value.
 3. The device of Claim 1, wherein the device performs the calculation of the learned value every a predetermined time period has elapsed, wherein the device performs the setting of the supplied fuel amount correction value every a predetermined time period has elapsed in the case that the device sets the supplied fuel amount correction value by using the learned value, the timings of the setting of the supplied fuel amount correction value and the calculation of the learned value being set such that the time period from the performance of the setting of the supplied fuel amount correction value to the calculation of the learned value immediately thereafter is shorter than that from the setting of the supplied fuel amount correction value to the calculation of the learned value immediately thereafter, and wherein the device performs the setting of the supplied air amount correction value every a predetermined time has elapsed in the case that the device sets the supplied air amount correction value by using the learned value, the timings of the setting of the supplied air amount correction value and the calculation of the learned value being set such that the time period from the setting of the supplied air amount correction value to the calculation of the learned value immediately thereafter is shorter than that from the setting of the supplied air amount correction value to the calculation of the learned value immediately thereafter.
 4. The device of any of Claims 1 to 3, wherein the device sets an upper limit or a lower limit value of the learned value, wherein the device limits the calculated learned value to the upper limit value when this learned value is larger than the upper limit value or limits the calculated learned value to the lower limit value when this learned value is smaller than the lower limit value, and wherein the device sets the learned value expected to be calculated when a supplied fuel injection amount difference amount is a predetermined amount as the upper or lower limit value, which difference amount being an amount of the difference of the actual supplied fuel amount relative to the estimated supplied fuel amount.
 5. The device of Claim 4, wherein the device determines the predetermined supplied fuel amount difference amount on the basis of at least one of the supplied fuel amount and the the pressure of the fuel supplied from the fuel supply means.
 6. The device of any of Claims 4 and 5, wherein the predetermined supplied fuel amount difference is one of the maximum and minimum values of the expected supplied fuel amount difference amount.
 7. The device of any of Claims 1 to 3, wherein the device sets the upper or lower value of the learned value, wherein the device limits the calculated value to the upper limit value when the learned value is larger than the upper limit value and limits the calculated value to the lower limit value when the learned value is smaller than the lower limit value, and wherein the device sets the learned value expected to be calculated when the supplied air amount difference amount is a predetermined supplied air amount as one of the upper and lower limit values, which supplied air amount difference amount being an amount of the difference of the estimated supplied air amount relative to the actual supplied air amount.
 8. The device of Claim 7, wherein the device determines the predetermined supplied air amount differ-

ence amount on the basis of the supplied air amount.

9. The device of Claim 7 or 8, wherein the predetermined supplied air amount difference amount is the maximum or minimum value of the expected supplied air amount. 5
10. The device of any of Claims 1 to 9, wherein the supplied fuel amount correction value is a correction value for decreasing a difference of the actual supplied fuel amount relative to an estimated supplied fuel amount which is an estimated value of the supplied fuel amount. 10
11. The device of any of Claims 1 to 10, wherein the supplied air amount correction value is a correction value for decreasing a difference of an estimated supplied air amount which is an estimated value of the supplied air amount relative to the actual supplied air amount. 15 20
12. A control device of an internal combustion engine comprising:
 - means for acquiring an estimated value of a supplied fuel amount which is an amount of a fuel supplied to a combustion chamber as an estimated supplied fuel amount; 25
 - means for acquiring an estimated value of a supplied air amount which is an amount of an air supplied to the combustion chamber as an estimated supplied air amount; 30
 - means for calculating an air-fuel ratio of a mixture gas formed in the combustion chamber as an estimated air-fuel ratio on the basis of the estimated supplied fuel and air amounts; 35
 - means for acquiring an actual air-fuel ratio of the mixture gas formed in the combustion chamber as an actual air-fuel ratio; 40
 - correction value calculation means for calculating a correction value for correcting the supplied air amount such that an air-fuel ratio difference which is a difference of the actual air-fuel ratio relative to the estimated air-fuel ratio becomes small; and 45
 - learning means for calculating and memorizing a learned value of the correction value by integrating the correction values calculated by the correction value calculation means, 50
 - wherein the device corrects the supplied air amount by only the learned value when no air-fuel ratio difference occurs and the device corrects the supplied air amount by the learned value and the correction value when the air-fuel ratio difference occurs, 55
 - wherein in the case that a supplied fuel amount difference where the actual supplied fuel amount is larger than the estimated supplied fuel

amount occurs and is the largest one within an expected range under the condition where the estimated supplied air amount corresponds to the actual supplied air amount, the device obtains the learned value when the air-fuel ratio difference becomes zero as a maximum lean-side learned value due to the supplied fuel amount difference,

wherein in the case that a supplied fuel amount difference where the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs and is largest one within an expected range under the condition where the estimated supplied air amount corresponds to the actual supplied air amount, the device obtains the learned value when the air-fuel ratio difference becomes zero as a maximum rich-side learned value due to the supplied fuel amount difference,

wherein in the case that a supplied air amount difference where the estimated supplied air amount is larger than the actual supplied air amount occurs and is the largest one within an estimated range under the condition where the estimated supplied fuel amount corresponds to the actual supplied fuel amount, the device obtains the learned value when the air-fuel ratio difference becomes zero as a maximum lean-side learned value due to the supplied air amount difference,

wherein in the case that a supplied air amount difference where the estimated supplied air amount is smaller than the actual supplied air amount occurs and is the largest one within an expected range under the condition where the estimated supplied fuel amount corresponds to the actual supplied fuel amount, the device obtains the learned value when the air-fuel ratio difference becomes zero as a maximum rich-side learned value due to the supplied air amount difference,

wherein the device sets the larger one of the maximum lean-side learned values due to the supplied fuel amount difference and due to the supplied air amount difference to an upper limit lean-side learned value,

wherein the device sets the larger one of the maximum rich-side learned values due to the supplied fuel amount difference and due to the supplied air amount difference,

wherein when the learned value calculated by the learning means is a value for increasing the supplied air amount and is larger than the upper limit lean-side learned value, the device limits the learned value to the upper limit lean-side learned value, and

wherein when the learned value calculated by the learning means is a value for decreasing the

supplied air amount and is larger than the upper limit rich-side learned value, the device limits the learned value to the upper limit rich-side learned value.

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13. The device of Claim 12, wherein the maximum lean-side and rich-side learned values due to the supplied fuel amount difference are those defined by at least one of the estimated supplied fuel amount and the pressure of a fuel supplied from fuel supply means. 10
14. The device of Claim 12 or 13, wherein the maximum rich-side and lean-side learned values due to the supplied air amount difference are those defined by the estimated supplied air amount. 15
15. A control device of an internal combustion engine, comprising:
- means for acquiring an estimated value of a supplied fuel amount which is an amount of a fuel supplied to a combustion chamber as an estimated supplied fuel amount; 20
- means for acquiring an estimated value of a supplied air amount which is an amount of an air supplied to the combustion chamber as an estimated supplied air amount; 25
- means for calculating an air-fuel ratio of a mixture gas formed in the combustion chamber as an estimated air-fuel ratio on the basis of the estimated supplied fuel and air amounts; 30
- means for acquiring an actual air-fuel ratio of the mixture gas formed in the combustion chamber as an actual air-fuel ratio; 35
- correction value calculation means for calculating a correction value for correcting the supplied air amount such that an air-fuel ratio difference which is a difference of the actual air-fuel ratio relative to the estimated air-fuel ratio is decreases; and 40
- learning means for calculating and memorizing a learned value of the correction value by integrating the correction values calculated by the correction value calculation means, 45
- wherein the device corrects the supplied air amount by only the learned value when no air-fuel ratio difference occurs and the device corrects the supplied air amount by the learned value and the correction value when the air-fuel ratio difference occurs, 50
- wherein in the case that a supplied fuel amount difference where the actual supplied fuel amount is larger than the estimated supplied fuel amount occurs and is the largest one within an estimated range and a supplied air amount difference where the estimated supplied air amount is larger than the actual supplied air amount occurs and is the largest one within an 55

expected range, the device sets the learned value when the air-fuel ratio difference becomes zero to an upper limit lean-side learned value, wherein in the case that a supplied fuel amount difference where the actual supplied fuel amount is smaller than the estimated supplied fuel amount occurs and is the largest one within an expected range and a supplied air amount difference wherein the estimated supplied air amount is smaller than the actual supplied air amount occurs and is the largest one within an estimated range, the device sets the learned value to an upper limit rich-side learned value, wherein when the learned value calculated by the learning means is a value for increasing the supplied air amount and is larger than the upper limit lean-side learned value, the device limits the learned value to the upper limit lean-side learned value, and

wherein when the learned value calculated by the learning means is a value for decreasing the supplied air amount and is larger than the upper limit rich-side learned value, the device sets the learned value to the upper limit rich-side learned value.

16. The device of Claim 15, wherein the upper limit rich-side and lean-side learned values are those defined by the estimated supplied air amount and at least one of the estimated supplied fuel amount and the pressure of a fuel supplied from fuel supply means.
17. The device of any of Claims 12 to 16, wherein the engine further comprises exhaust gas recirculation means for introducing an exhaust gas discharged from the combustion chamber to an exhaust passage into an intake passage and the correction value calculated by the correction value calculation means is a value for correcting an amount of the exhaust gas introduced into the intake passage by the exhaust gas recirculation means.

FIG.1

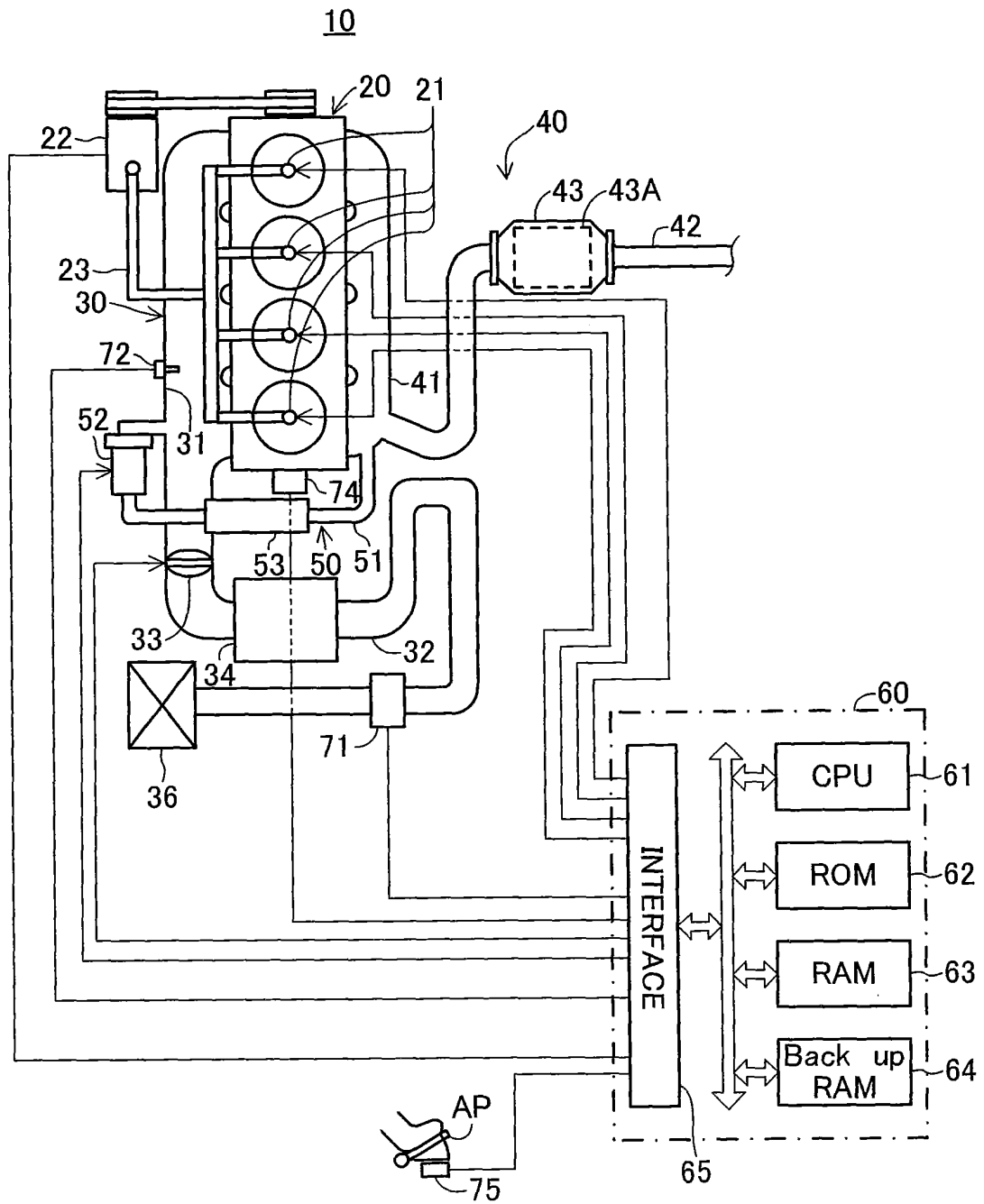


FIG.2

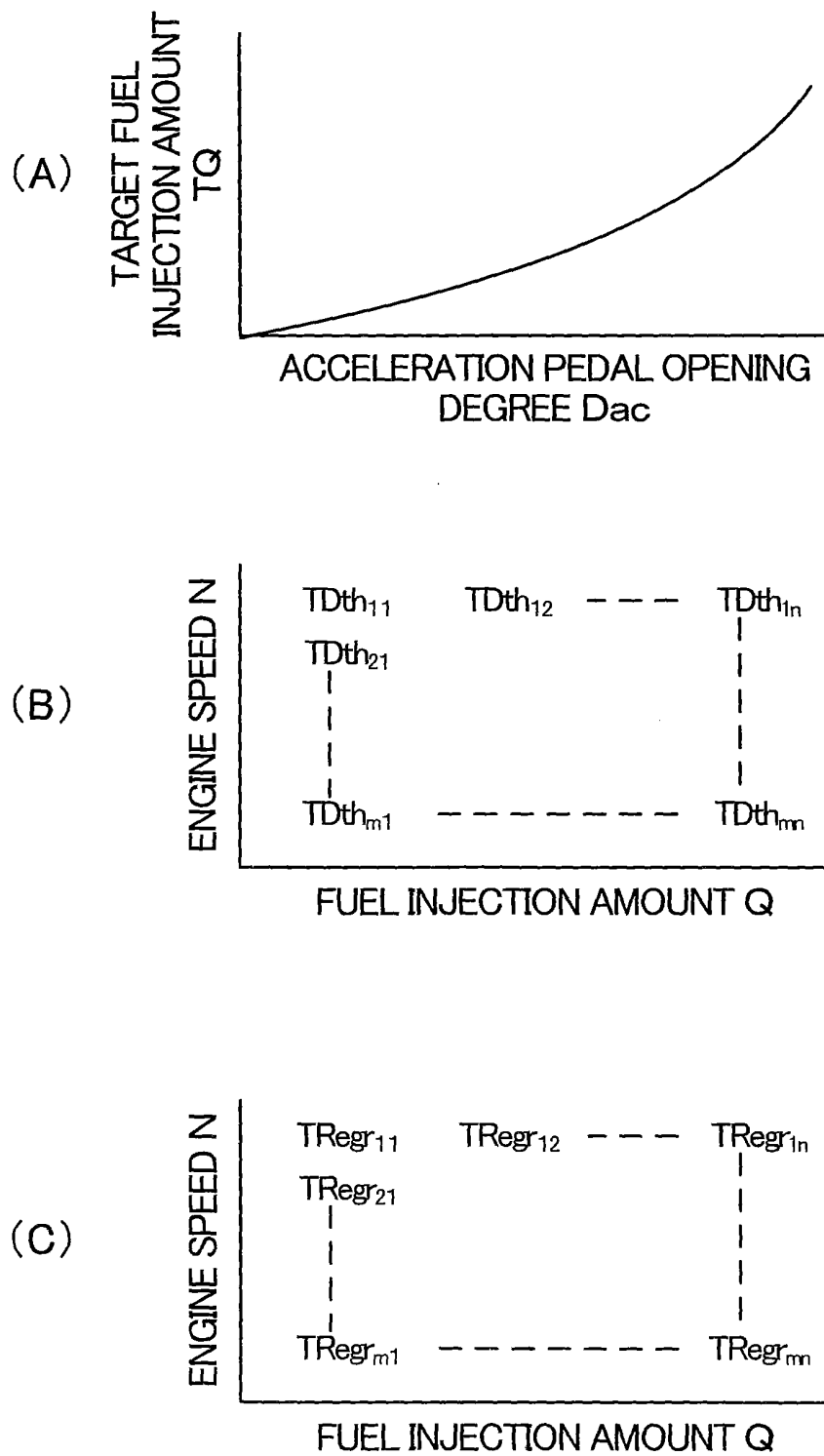


FIG.3

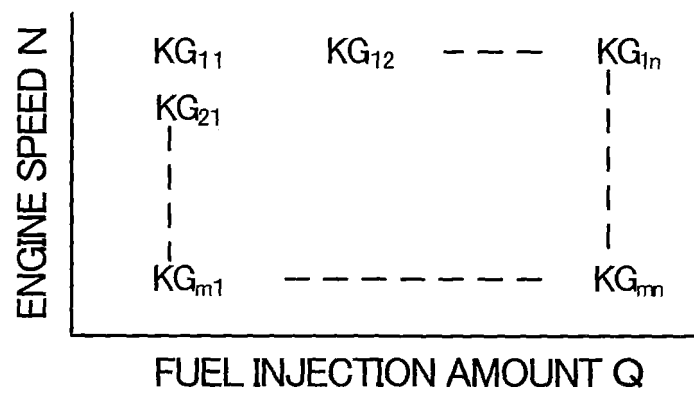


FIG.4

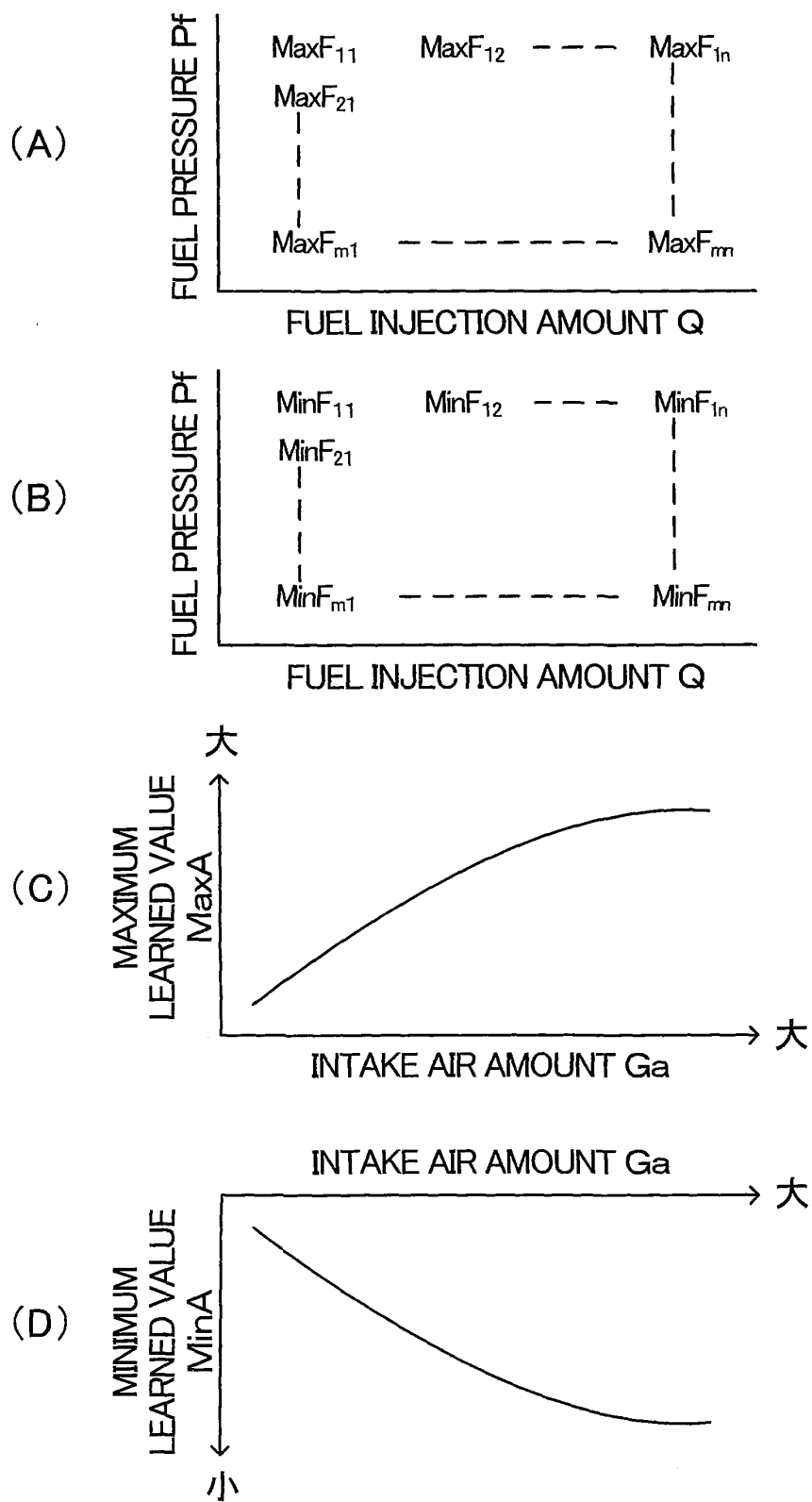


FIG.5

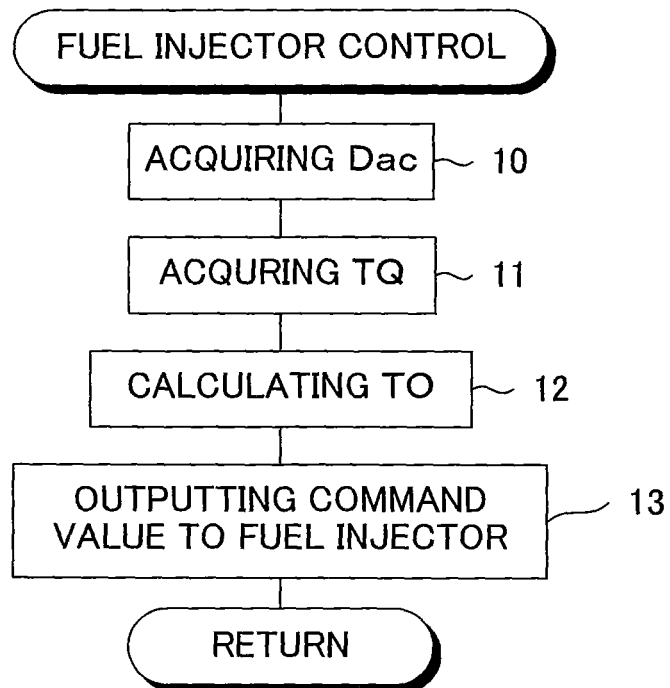


FIG.6

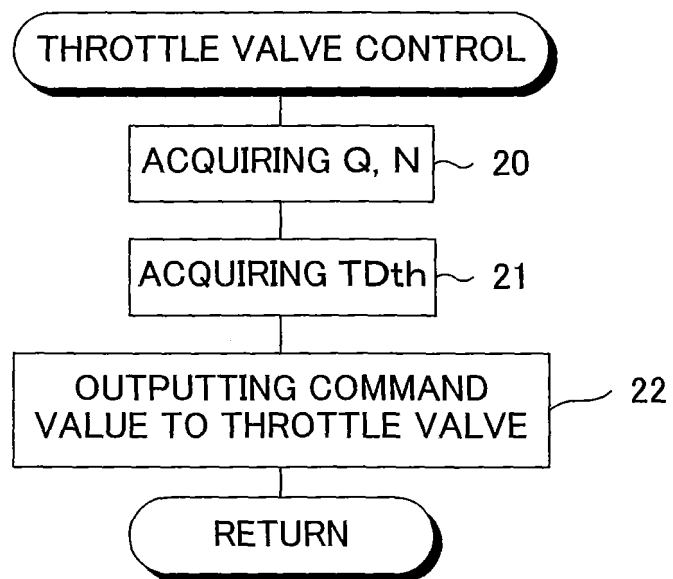


FIG.7

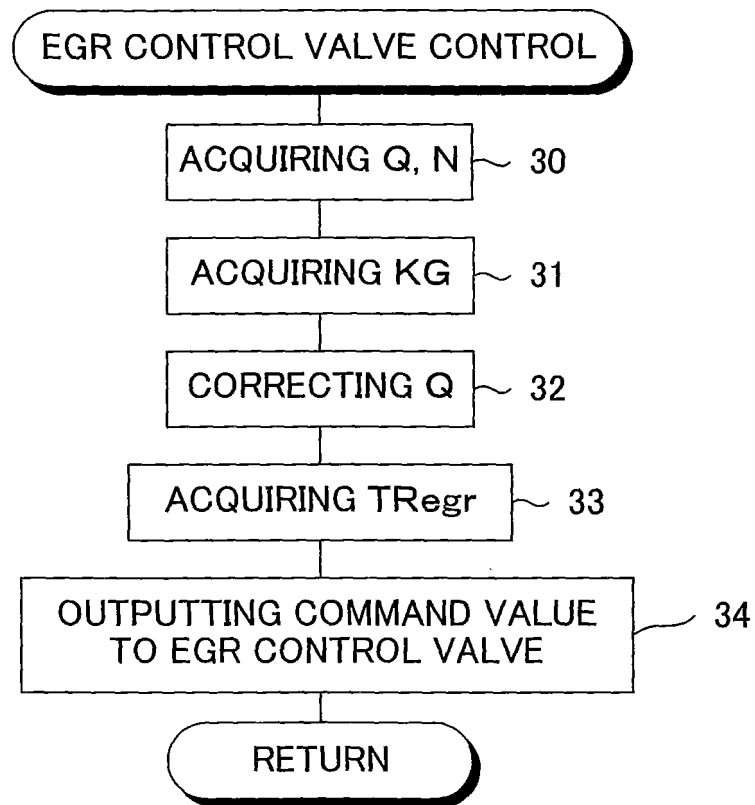


FIG.8

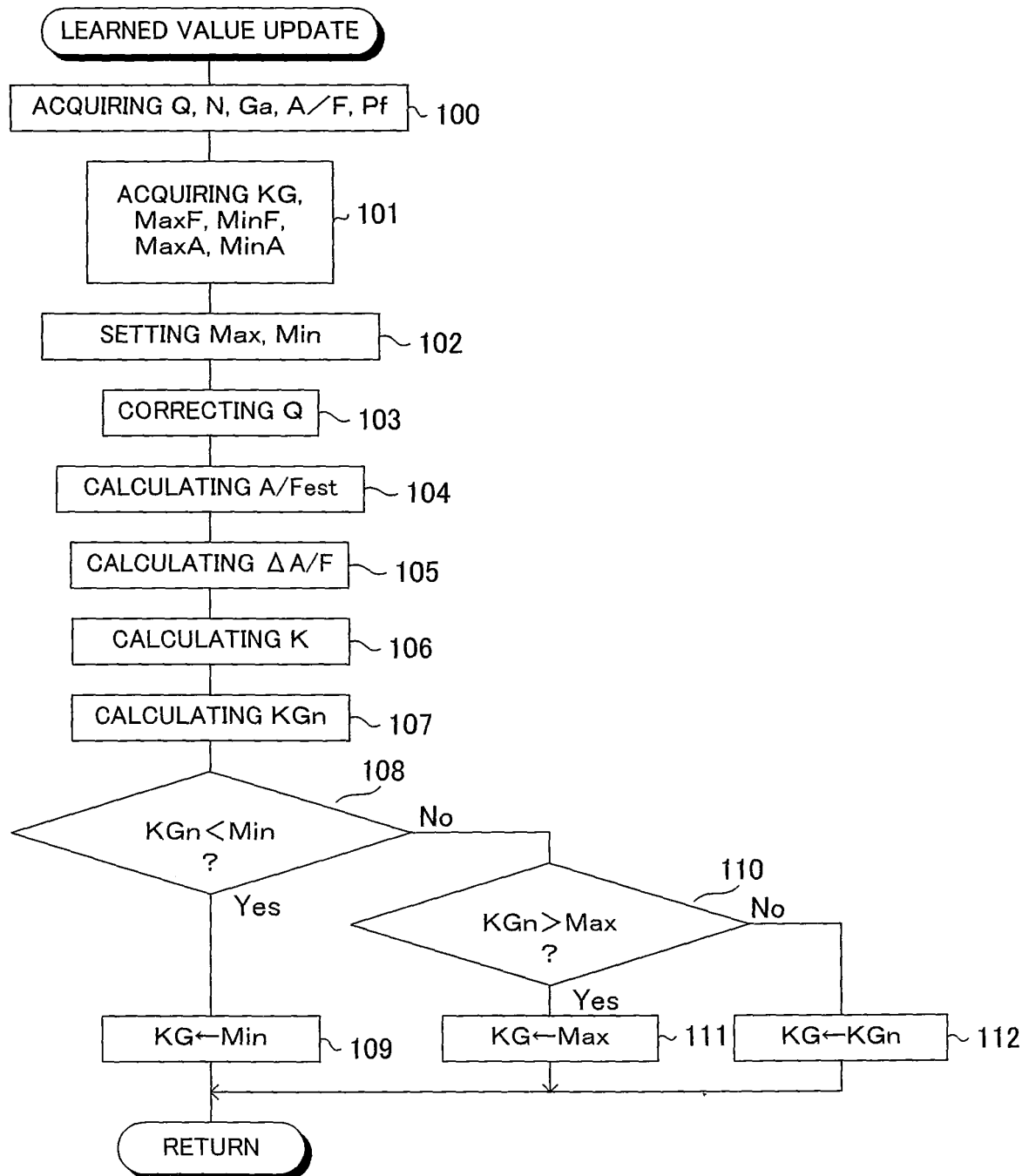


FIG.9

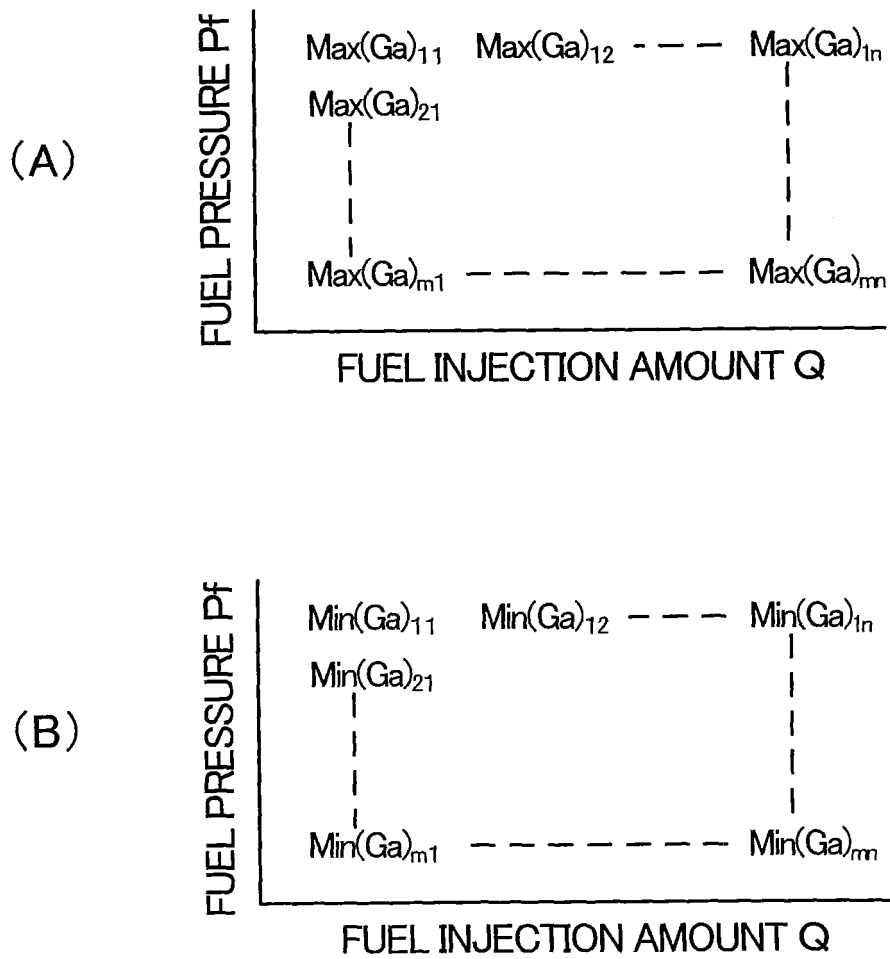


FIG.10

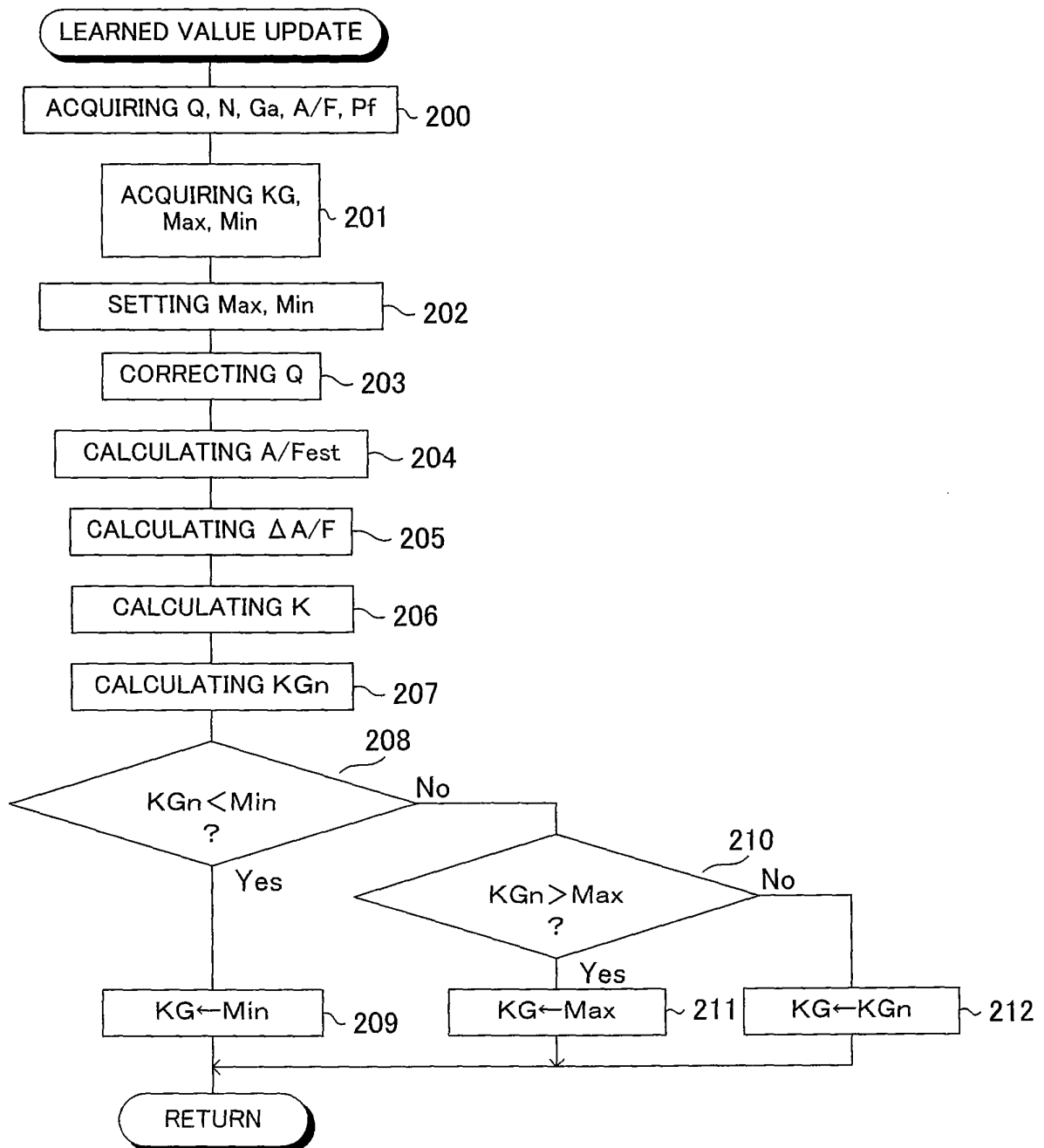


FIG.11

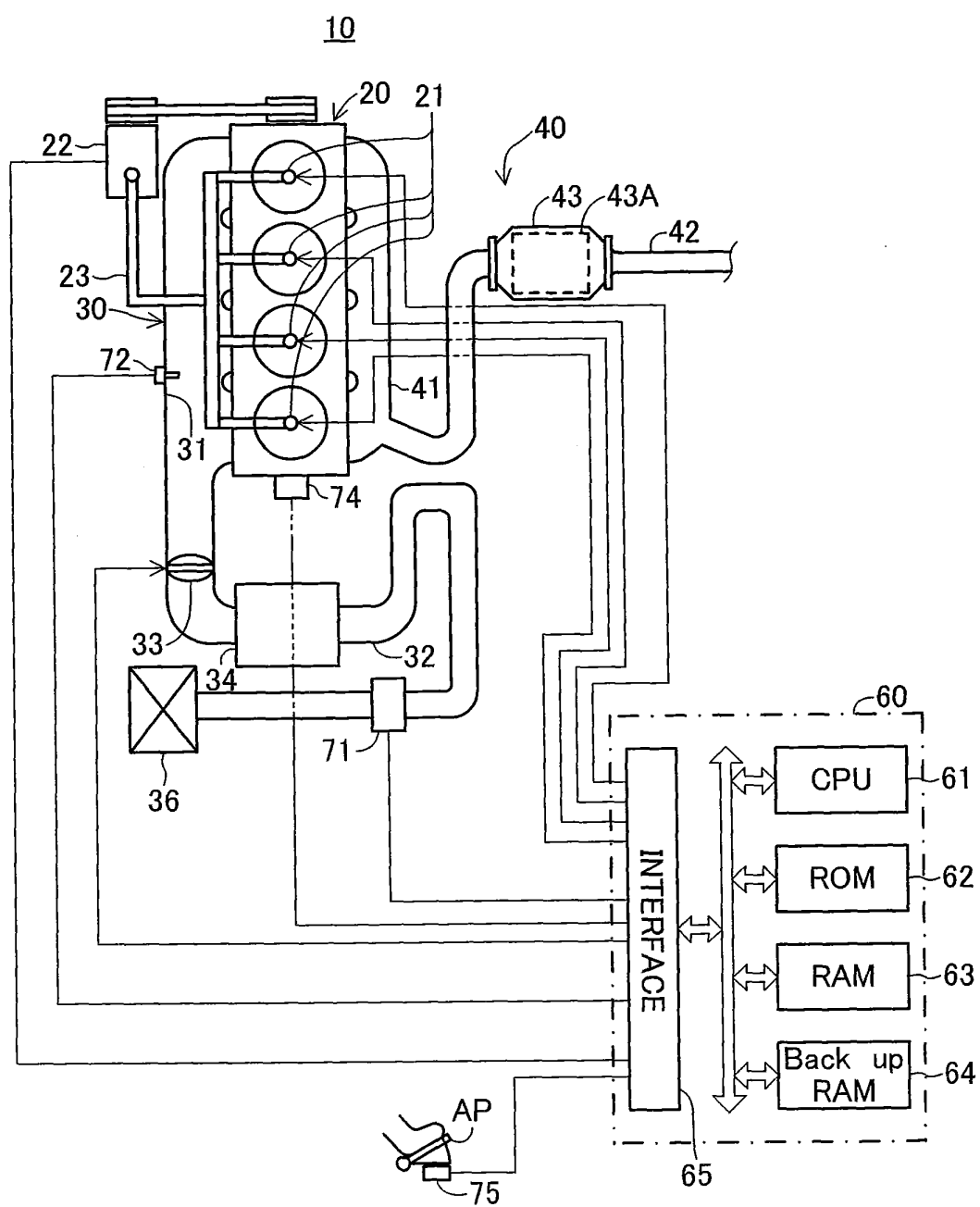


FIG.12

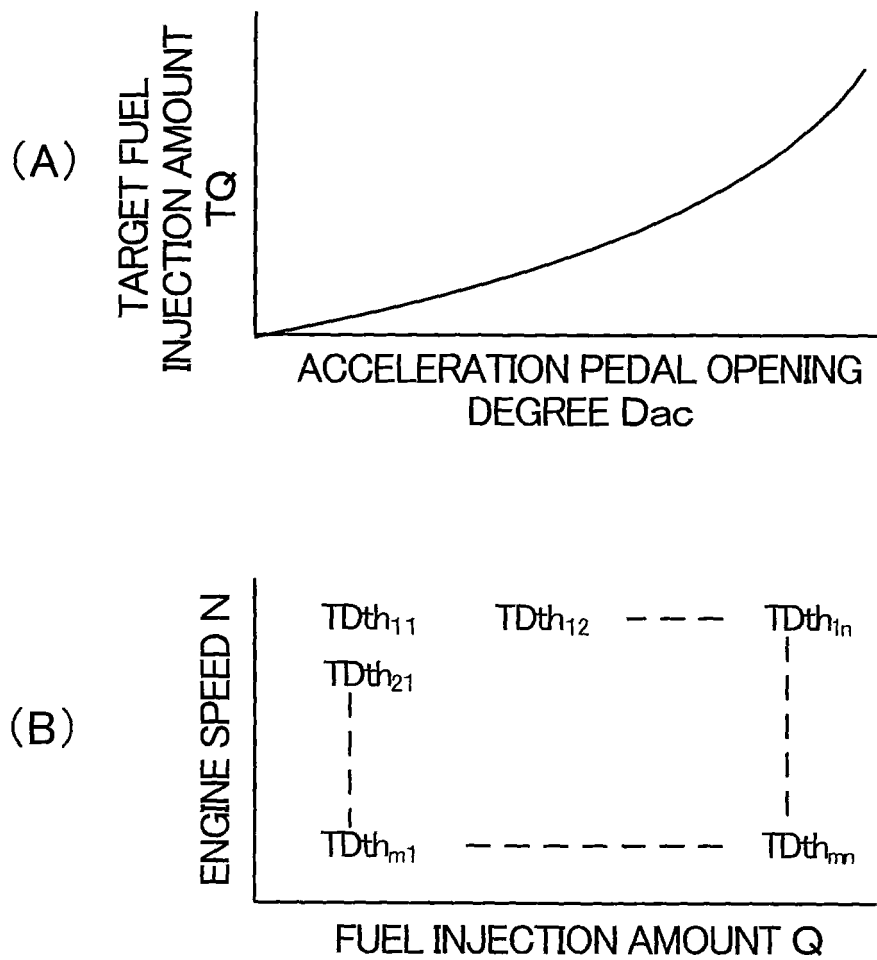


FIG.13

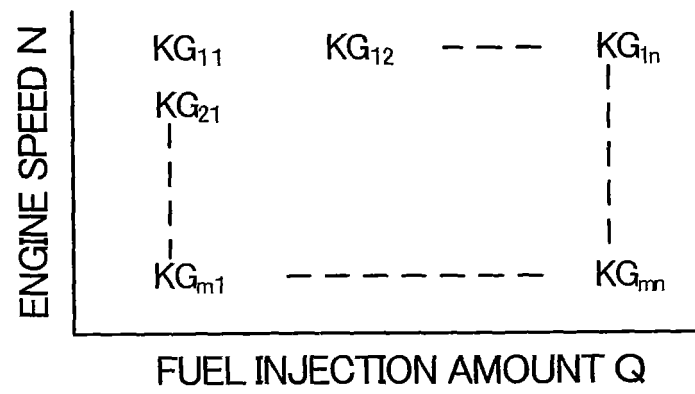


FIG.14

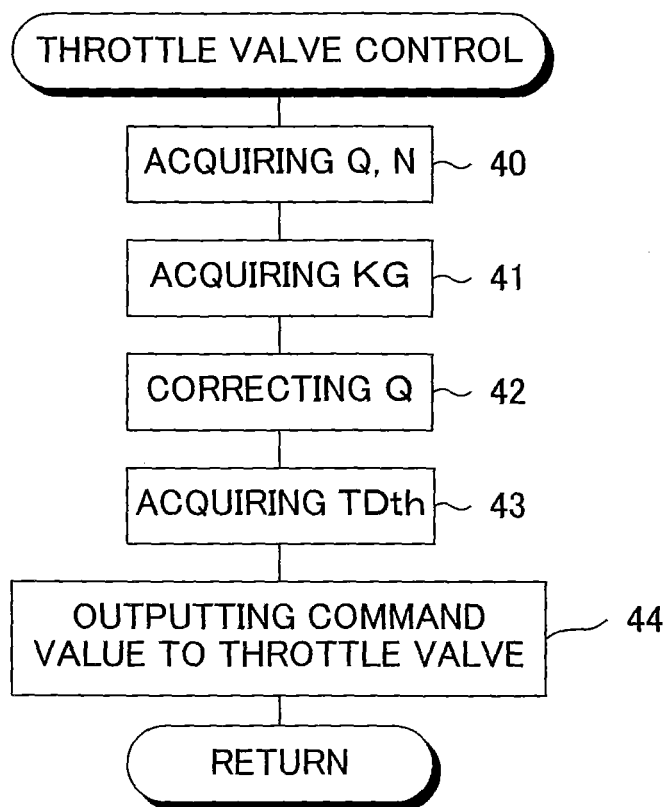


FIG.15

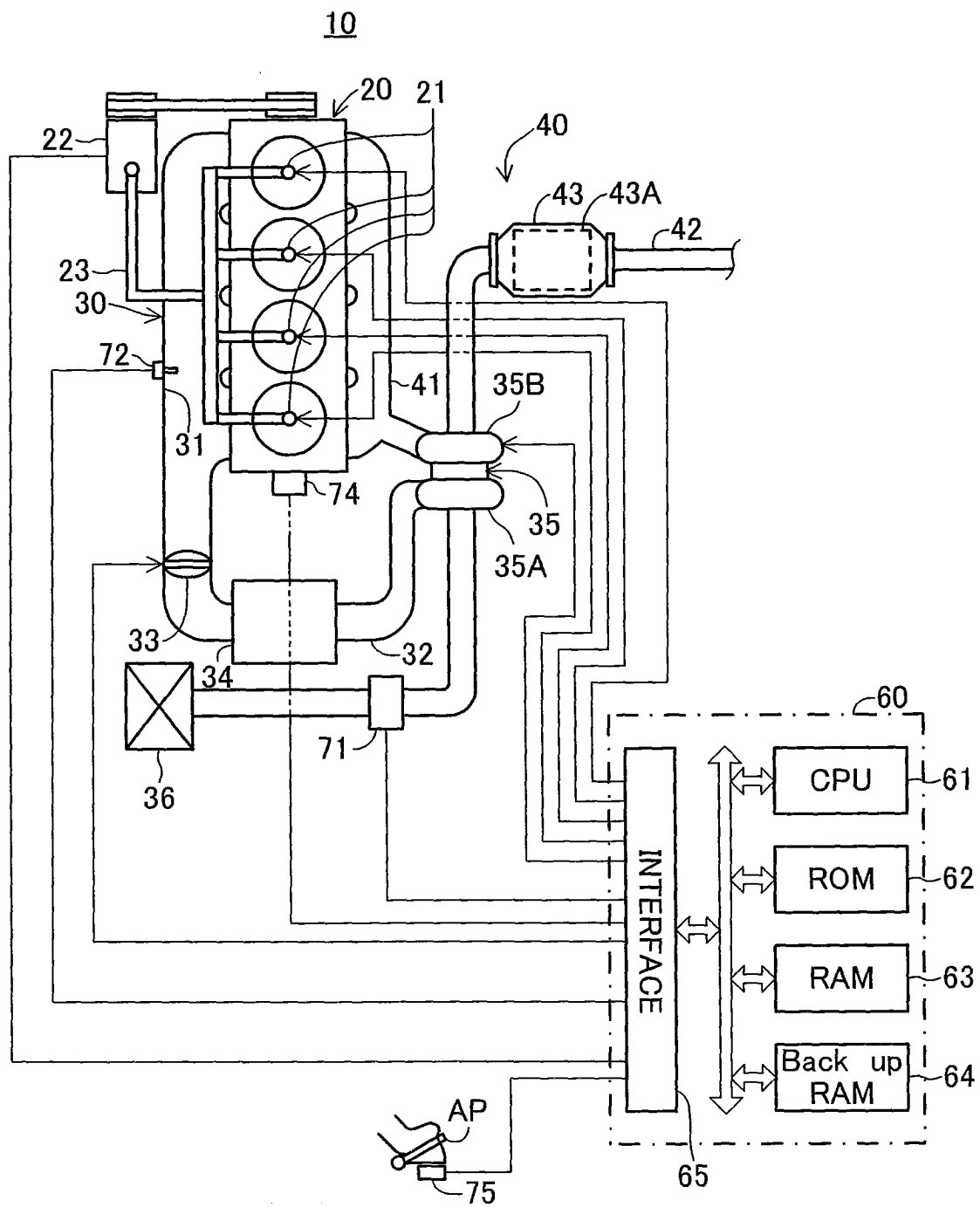


FIG.16

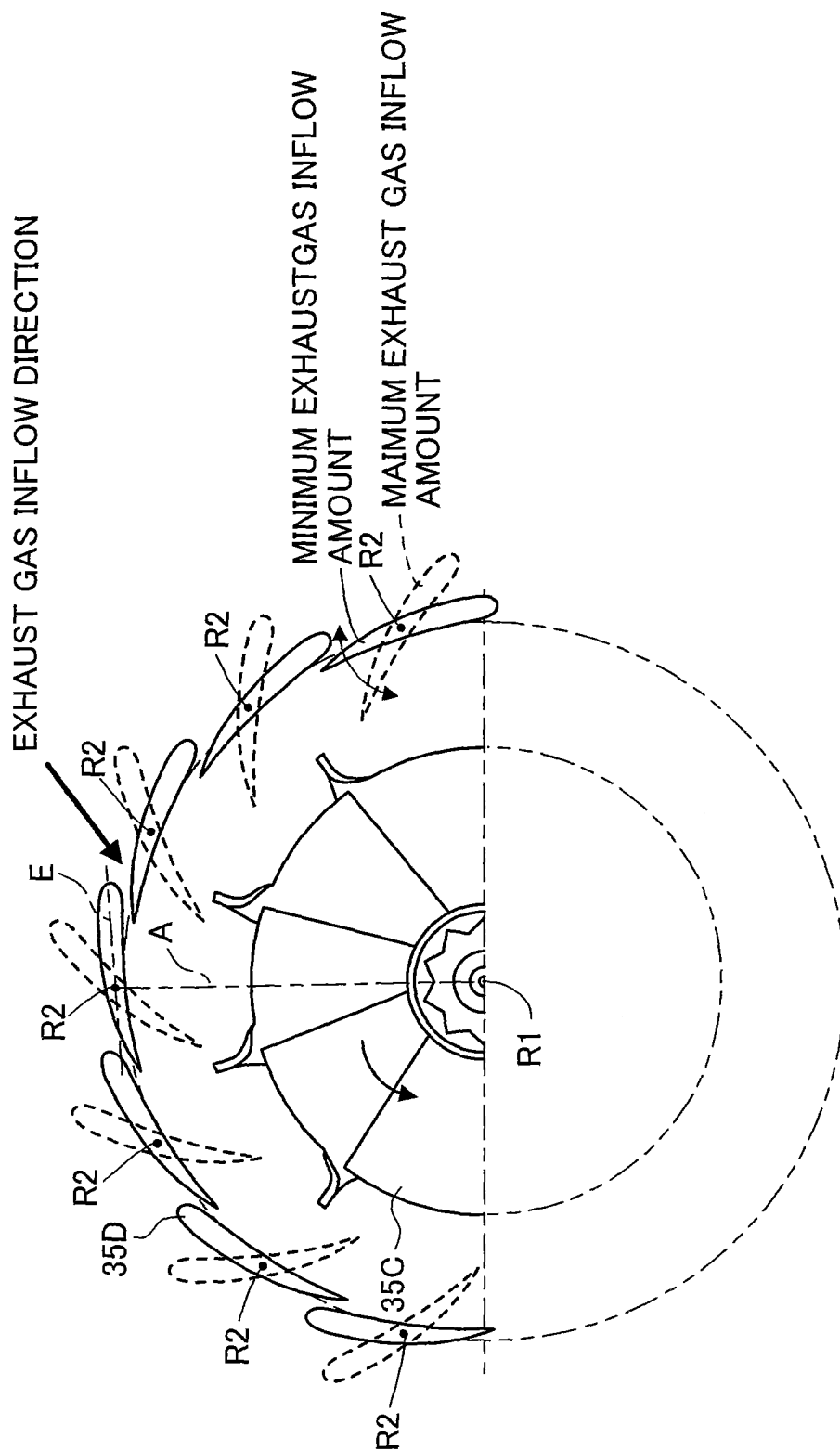


FIG.17

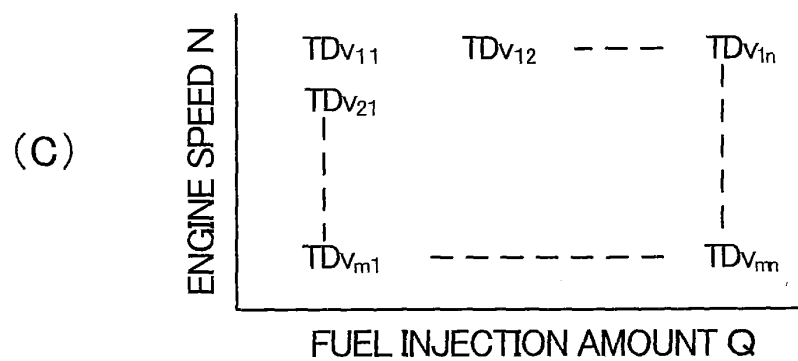
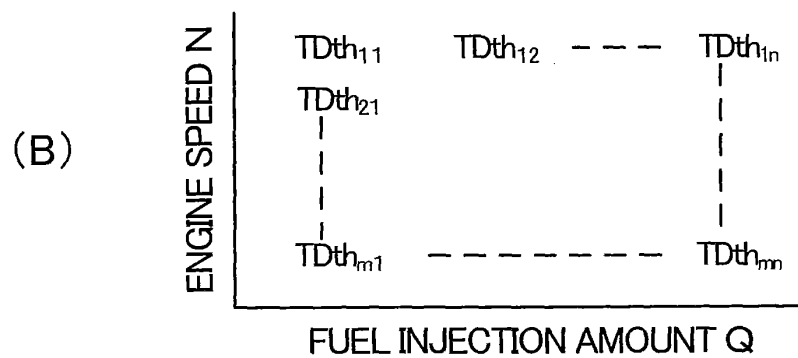
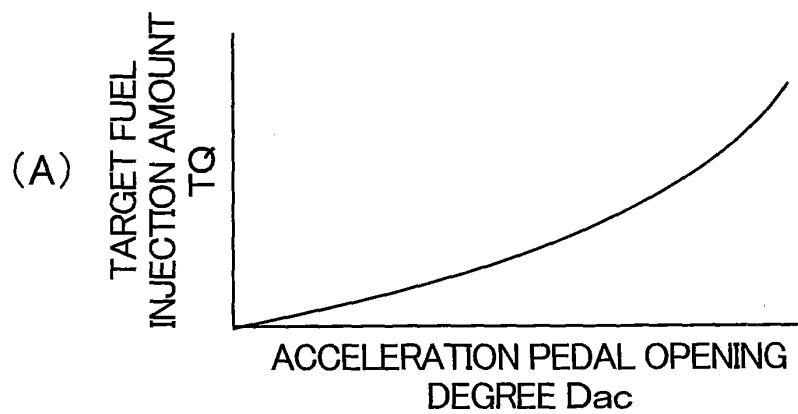


FIG.18

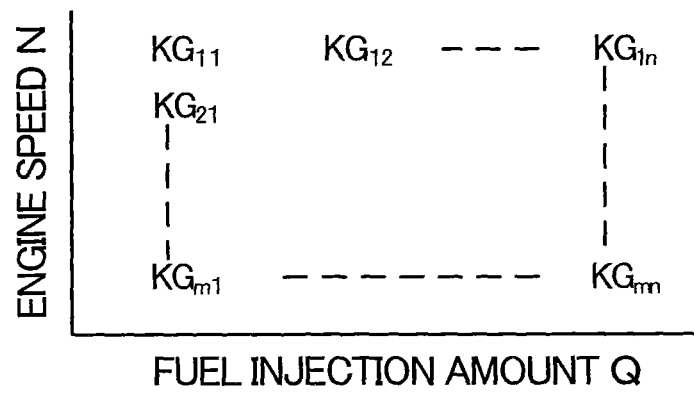


FIG.19

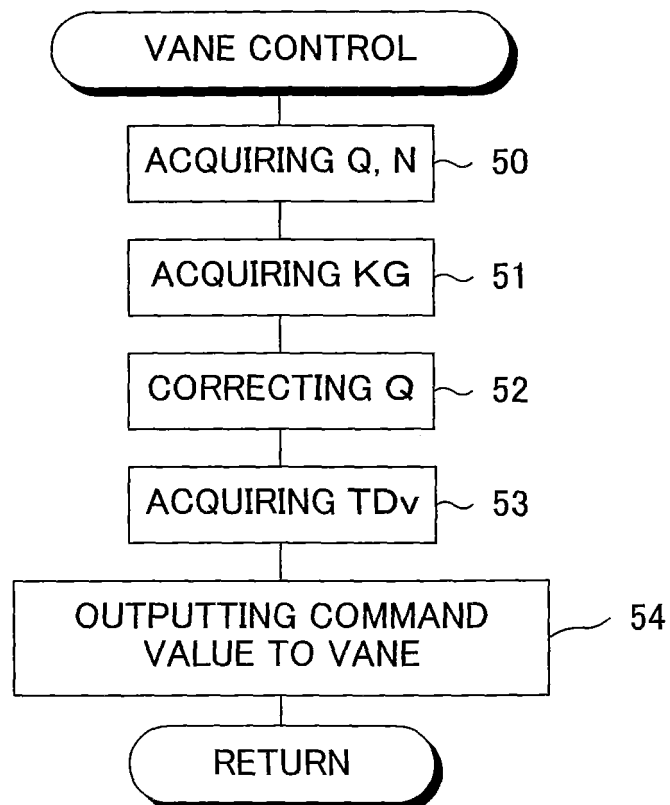


FIG.20

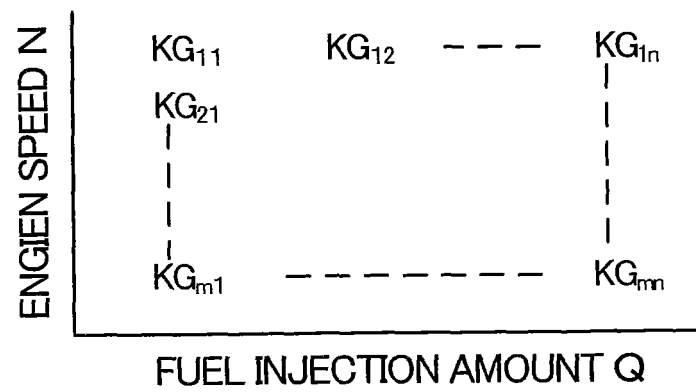


FIG.21

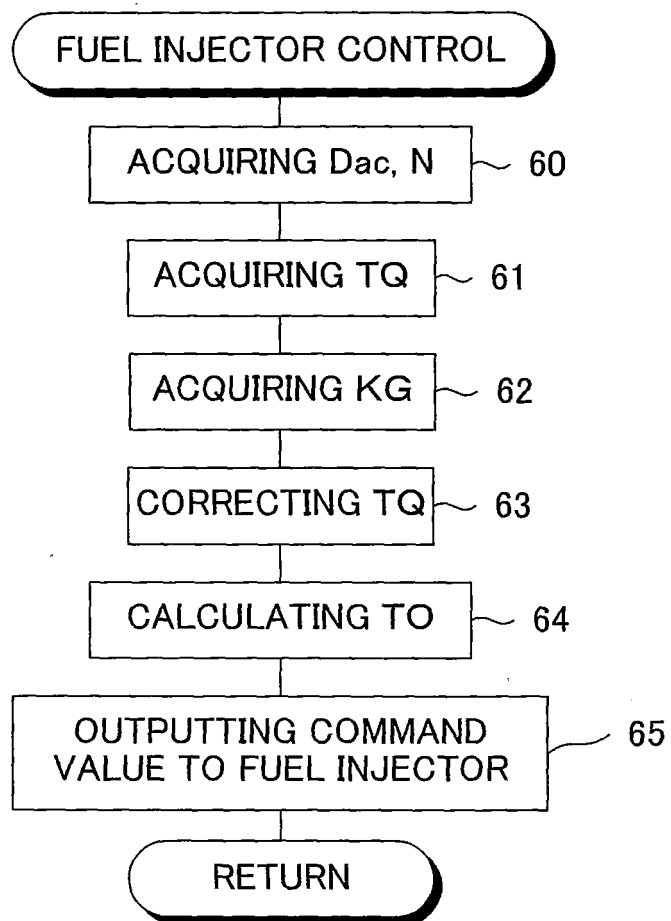


FIG.22

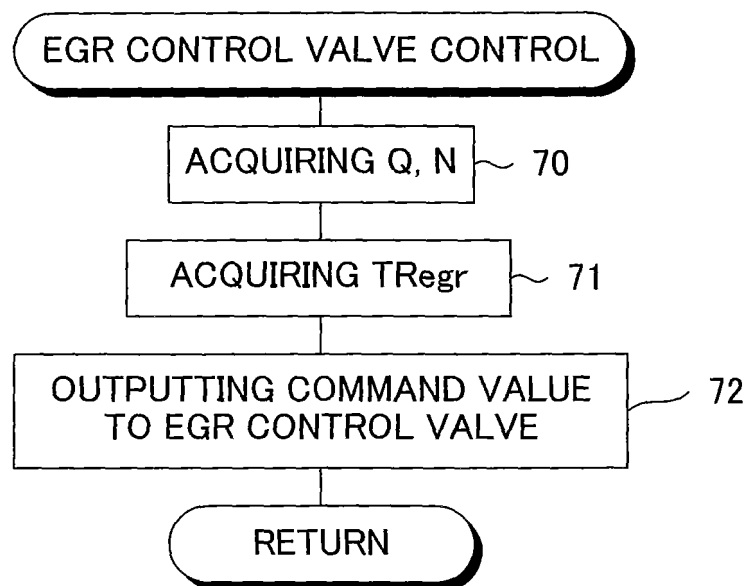
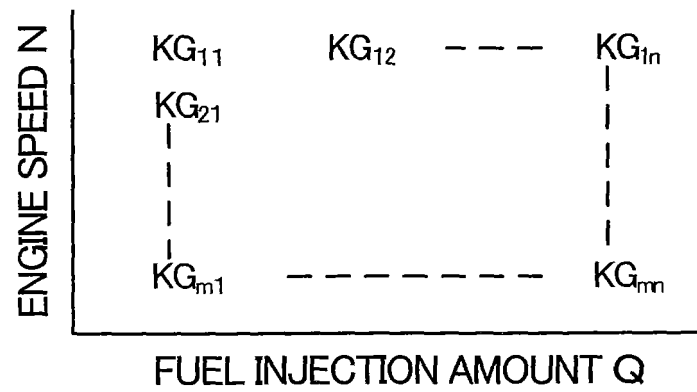


FIG.23



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/073109

A. CLASSIFICATION OF SUBJECT MATTER

F02D41/14(2006.01)i, F02D21/08(2006.01)i, F02D45/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02D41/14, F02D21/08, F02D45/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2001-073845 A (Toyota Motor Corp.), 21 March 2001 (21.03.2001), paragraphs [0029], [0030], [0032], [0035], [0038], [0040], [0042], [0047] to [0051], [0059] to [0062], [0086] to [0095]; fig. 1 to 3, 8, 9 (Family: none)	1, 2, 4-11 3, 12-17
Y A	JP 2005-113877 A (Denso Corp.), 28 April 2005 (28.04.2005), paragraphs [0023], [0024], [0027], [0028], [0031], [0040], [0051] to [0059], [0084] to [0091], [0048]; fig. 1, 6, 13, 17 (Family: none)	1, 2, 4-11 3, 12-17

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
03 February, 2011 (03.02.11)Date of mailing of the international search report
15 February, 2011 (15.02.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/073109

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2003-120381 A (Nissan Motor Co., Ltd.), 23 April 2003 (23.04.2003), paragraphs [0009], [0013] & US 2003/0070421 A1 & EP 1302633 A2	1,2,4-11 3,12-17
Y A	JP 2000-073885 A (Toyota Motor Corp.), 07 March 2000 (07.03.2000), paragraphs [0044], [0062] to [0067]; fig. 8 & US 6234156 B1 & EP 0984154 A2	4-11 1-3,12-17
A	JP 2009-002301 A (Denso Corp.), 08 January 2009 (08.01.2009), paragraphs [0035] to [0047]; fig. 1, 2 & DE 102008002620 A1	1-17

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/073109

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The invention in claim 1 and the inventions in claims 12, 15 have such a common technical feature as "a control device for an internal combustion engine comprising a fuel supply means for supplying a fuel into a combustion chamber and an air supply means for supplying air into the combustion chamber, wherein the air/fuel ratio of the mixed gas which is produced in the combustion chamber according to the fuel supply amount and the air supply amount is controlled, the air supply amount is corrected according to the learned value".

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/073109

Continuation of Box No.III of continuation of first sheet(2)

However, the above-said technical feature cannot be considered to be a special technical feature, since said technical feature does not make a contribution over the prior art in the light of the contents disclosed in the document 1 (JP 2001-073845 A). Furthermore, there is no other same or corresponding special technical feature between the invention in claim 1 and the inventions in claims 12, 15. Therefore, the invention in claim 1 and the inventions in claims 12, 15 have no same or corresponding special technical feature.

In conclusion, three invention groups comprising claims 1 - 11; claims 12 - 14 and claim 17 referring to claims 12 - 14; and the inventions in claims 15 - 17 are involved in claims.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2005023937 A [0007]