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(54) Fuel injection amount learning method for internal combustion engine

(57) A learning method for an internal combustion engine (10) may include steps as follows. Injection for learning is executed from an injector (43A to 43D) during non-injection operation of the engine (10) with a timing. A correction amount for the injector (43A to 43D) is obtained based on an RPM fluctuation amount of the engine (10) due to the injection for learning and on the RPM of the engine (10). A controller (30) determines whether or not a learning control execution condition is satisfied with a predetermined condition with the timing. The controller (30) executes the learning control when the learning control execution condition is satisfied with the predetermined condition. The controller (30) obtains an execution frequency of the learning control. The controller (30) forcibly increases the execution frequency of the learning control when the execution frequency obtained in a previous step has not attained a predetermined frequency.

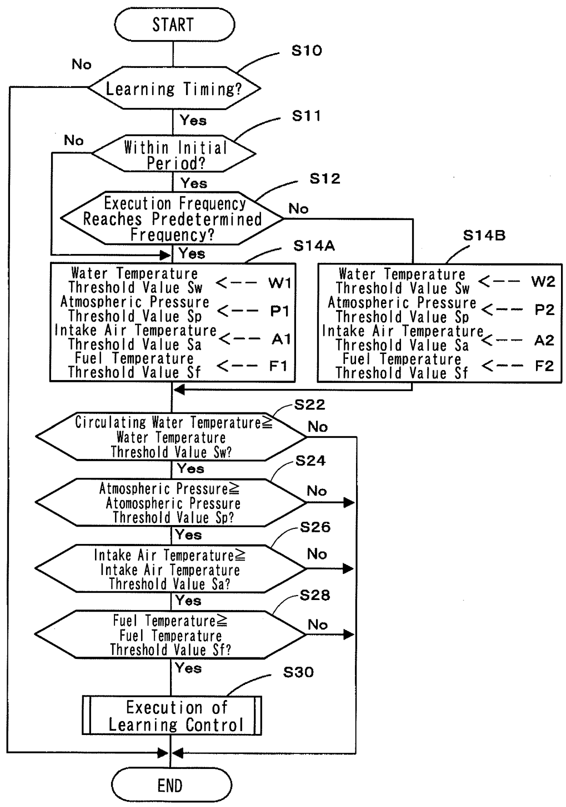

FIG. 4

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Description

[0001] This application claims priority to Japanese patent application serial number 2012-177001, the contents of which are incorporated herein by reference.

[0002] The present invention relates to a learning method related to a fuel injection amount of an internal combustion engine. In such a learning control, an injector injects an amount of fuel during non-injection operation of the internal combustion engine to observe the behavior of the internal combustion engine. In this way, it can obtain a required correction amount for the injector.

[0003] A diesel engine (internal combustion engine) configured to perform pilot injection has conventionally been known. In the diesel engine, the injector injects high-pressure fuel into a cylinder. Prior to main fuel injection, pilot injection occurs, i.e., a minute amount of fuel is injected, that is. This helps to relieve combustion noise and to suppress NOx. To obtain the above result to a sufficient degree, it is necessary to accurately determine the amount injected during the pilot injection.

[0004] However, there may exist a difference between the amount of fuel programmed to be injected and the actual amount injected by actually the injector. As shown in FIG. 2, the deviation amount does not remain constant but undergoes a change throughout an accumulation period. Further, differences may occur from injector to injector. In view of this, fuel injection amount learning control is performed with appropriate timing to estimate the deviation amount at any point in time, thereby obtaining a correction amount for the injector.

[0005] In the learning control as disclosed in Japanese Laid-Open Patent Publication No. 2005-36788, injection for learning (single-shot injection) from the injector is executed during non-injection operation, in which the command injection amount of the internal combustion engine is zero or less. "Command injection" refers to the amount of fuel programmed by a user to be injected. The torque generated is calculated based on the RPM of the internal combustion engine and the amount of fluctuation in the RPM of the internal combustion engine during this control period. The actual injection amount is estimated from the calculated amount of torque. A deviation amount between the estimated actual injection amount and the command injection amount used for learning is obtained in order to calculate the correction amount.

[0006] In the present method, the fluctuation amount of the RPM of the internal combustion engine is used. Consequently, if the surrounding conditions of the internal combustion engine during the learning control are not constant, it may not be possible to obtain an accurate correction amount.

[0007] In the learning method as disclosed in Japanese Laid-Open Patent Publication No. 2009-57853, an environmental correction amount is calculated. This amount corresponds to the change in the operational environmental conditions of the internal combustion engine. By using this environmental correction amount, the actual injection amount estimated through the learning control is corrected. As a result, it is possible to obtain a more accurate injector correction amount.

[0008] In an environment in which it is impossible to obtain a sufficient fluctuation amount of the RPM of the internal combustion engine, the learning accuracy (accuracy of the correction amount) deteriorates. In view of this, in the conventional techniques as disclosed in Japanese Laid-Open Patent Publication No. 2005-36788 and Japanese Laid-Open Patent Publication No. 2009-57853, the learning control is not executed when the execution condition for the learning control is not satisfied. For example, when the circulating water temperature of the internal combustion engine is lower than a predetermined temperature (i.e., during warming up), the learning control is not executed.

[0009] However, some users repeatedly perform short-range operations such as repeatedly driving a car a short distance. In the case of short-range operation, the internal combustion typically ends before the warming-up operation has been completed. Thus, in some cases, the circulating water temperature does not attain the predetermined temperature level, and the learning control is not executed. When the learning control is not executed, it is impossible to obtain an appropriate correction amount for the injector. As shown in FIG. 2, the deviation amount of the injection amount of the injector also fluctuates, so that, in some cases, even when pilot injection is performed, it is impossible to obtain a reduction in combustion noise and suppression of NOx as desired.

[0010] Accordingly, there are cases where an operation that does not easily allow execution of the learning control, e.g., short-range operation, is repeatedly performed. There has been a need for a learning method, which, even in such cases, allows for the performance of an appropriate learning control, thereby making it possible to obtain an appropriate correction amount for the injector.

[0011] According to a feature of the present invention, there is provided a fuel injection amount learning method for an internal combustion engine. In the method, injection for learning is executed from an injector during atypical operation of the internal combustion engine, and learning control is executed with timing. In the learning control, a correction amount for the injector is obtained based on an RPM fluctuation amount of the internal combustion engine due to the injection for learning and on the RPM of the internal combustion engine. The learning method includes a learning condition determination step, a learning execution step, a learning frequency determination step, and a learning frequency increase step. In the learning condition determination step, a controller determines whether or not a learning control execution condition is satisfied with a predetermined condition with the timing. When the controller determines that the execution condition is satisfied with the predetermined condition in the learning condition determination step, the learning control is executed in the learning execution step. In the learning frequency determination step, the controller obtains a learning control execution frequency. When the controller determines that the execution frequency obtained in the learning frequency determination step has not attained a predetermined frequency, the learning control execution frequency is forcibly increased in the learning frequency increase step.

[0012] Thus, due to the learning frequency increase step, it is possible to prevent the learning control from failing to be executed. As a result, even in the case where an operation that does not easily allow execution of learning control is repeatedly performed, it is possible to appropriately perform the learning control to obtain an appropriate correction amount for the injector.

[0013] The fuel injection amount learning method for the internal combustion engine may further include an initial period determination step. In the initial period determination step, the controller determines whether or not an accumulation period (obtained from the brand-new state of the injector) is within a predetermined initial period. When the controller determines that the accumulation period is within the predetermined initial period in the initial period determination step, and that the execution frequency obtained in the learning frequency determination step has not attained the predetermined frequency, a threshold value of the predetermined condition is changed so as to relieve the execution condition in the learning frequency increase step.

[0014] In the initial period, a change in the deviation amount of the injection amount of the injector is particularly large. However, when, in the initial period, the execution frequency has not attained a predetermined frequency, the threshold value for determining the execution condition for the learning control is changed so as to relieve the execution condition. As a result, during the initial period, when operations are repeatedly conducted yet they do not allow for the execution of the learning control, it is possible to appropriately conduct learning control to obtain an appropriate correction amount for the injector.

[0015] Instead of the above feature, it is also possible for a fuel injection amount learning method for an internal combustion engine according to the present invention to include a learning condition determination step, a learning execution step, and a learning frequency increase step. In the learning condition determination step, a controller determines whether or not a learning control execution condition is satisfied with a predetermined condition with the timing. In the learning execution step, the learning control is executed when the controller determines that the execution condition is satisfied with the predetermined condition in the learning condition determination step. In the frequency increase step, a threshold value is changed according to the fuel injection pressure from the injector. The threshold value is for determining whether or not the execution condition in the learning condition determination step is satisfied.

[0016] As a result, it is possible to appropriately ease the learning control execution condition. That is, even when operations are repeatedly conducted yet they do not allow for the execution of the learning control, it is possible to appropriately perform the learning control to obtain an appropriate correction amount for the injector.

[0017] The determination of the execution condition in the learning condition determination step may include a determination of the circulating water temperature of the internal combustion engine and a determination of the atmospheric pressure. In the learning frequency increase step, the threshold value for the determination of the circulating water temperature and the threshold value for the determination of the atmospheric pressure in the learning condition determination step may be changed.

[0018] As a result, even when, for example, the short-range operation is repeated, it is possible to appropriately perform the learning control to obtain an appropriate correction amount for the injector.

[0019] The execution condition determination in the learning condition determination step may include the determination of the circulating water temperature of the internal combustion engine, the determination of the atmospheric pressure, a determination of the temperature of the intake air of the internal combustion engine, and a determination of the fuel temperature. In the learning frequency increase step, at least one of the following threshold values which are used in the learning condition determination step, may be changed: a threshold value of the circulating water temperature, a threshold value of the atmospheric pressure, a threshold value for the determination of the intake air temperature, and a threshold value for the determination of the fuel temperature.

[0020] As a result, even when an operation not easily allowing the execution of learning control is repeated, it is possible to appropriately perform learning control to obtain an appropriate correction amount for the injector.

[0021] Additional objects, features, and advantages, of the present invention will be readily understood after reading the following detailed description together with the claims and the accompanying drawings, in which:

FIG. 1 is a schematic view of an internal combustion engine in which a fuel injection amount learning method of the present invention is applied;

FIG. 2 is a graph for showing an injection deviation amount from an injector for injecting fuel corresponding to an accumulation period;

FIG. 3 is a graph for showing a change in the injection deviation amount from the injector corresponding to a traveling distance, and for showing an effect of the learning control;

FIG. 4 is a flow chart of an example procedure according to a first embodiment;

FIG. 5 is a graph for showing an effect caused by the first embodiment;

FIG. 6 is a graph for showing a basic idea of a second embodiment; and

FIG. 7 is a flow chart of an example procedure according to the second embodiment.

[0022] Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved fuel injection amount learning methods for an internal combustion engine. Representative examples of the present invention, which utilize many of these additional features and teachings both separately and in conjunction with one another, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of ordinary skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful configurations of the present teachings.

[0023] An embodiment of the present invention will be described with reference to the drawings. FIG. 1 shows an internal combustion engine 10 consisting, for example, of a diesel engine. The engine 10 has cylinders 45A to 45D. An intake pipe 11 and an exhaust pipe 12 are connected to the engine 10. Intake air is introduced into the cylinders 45A to 45D from the intake pipe 11, and exhaust gas from the cylinders 45A to 45D is discharged to the exhaust pipe 12. The intake pipe 11 may be provided with an intake air temperature detection sensor (intake air temperature detection means) 24. A controller 30 can detect the temperature of the intake air based on a detection signal from the intake air temperature detection sensor 24.

[0024] The engine 10 may be provided with a rotation detection sensor (rotation detection means) 26. The rotation sensor 26 can detect an RPM of the internal combustion engine (e.g., RPM of a crankshaft), a rotational angle (e.g., a compression top dead center timing of each cylinder), etc. The controller 30 can detect the RPM, the rotational angle, etc. of the engine 10 based on a detection signal from the rotation sensor 26.

[0025] The engine 10 may be provided with a circulating water temperature detection sensor (circulation water temperature detection means) 22. The controller 30 can detect the circulating water temperature of the engine 10 based on a detection signal from the circulating water temperature detection sensor 22. The controller 30 can detect an atmospheric pressure based on a detection signal from an atmospheric pressure sensor (atmospheric pressure detection means) provided, for example, on the controller 30.

[0026] Fuel is supplied to a common rail 41 from a fuel tank (not shown). The fuel in the common rail 41 is maintained at high pressure, and is supplied to injectors 43A to 43D via fuel pipes 42A to 42D. The common rail 41 is provided with a fuel pressure sensor (fuel pressure detection means) 21 and a fuel temperature sensor (fuel temperature detection means) 25. The controller 30 can detect the pressure of the fuel in the common rail 41 based on a detection signal from the fuel pressure sensor 21. The controller 30 can detect the fuel temperature in the common rail 41 based on a detection signal from the fuel temperature sensor 25.

[0027] Injectors 43A to 43D are provided on the cylinders 45A to 45D, respectively, and are configured to inject a predetermined amount of fuel into the cylinders with a predetermined timing in response to a control signal from the controller 30. The controller 30 takes in detection signals from various sensors, detects an operational condition of the engine 10, and outputs a control signal for driving the injectors 43A to 43D.

[0028] FIG. 2 shows a deviation amount of an injection amount with respect to an accumulation period in the injectors 43A to 43D. The injection deviation amount is a deviation amount between the injection amount as commanded by the controller 30 (command injection amount) and the actual injection amount.

[0029] As shown in FIG. 2, generally speaking, the injection deviation amount undergoes a relatively great change during the initial period. The deviation amount after an elapse of the initial period is smaller than that during the initial period. The initial period occurs during the start of the use of the injector when the accumulation period is not more than a predetermined period. That is, the initial period is a period in which the accumulation period from a brand-new state is not more than a predetermined period.

[0030] In determining the initial period, there is estimated, for example, a temperature at which an injector nozzle is heated during the operation of the internal combustion engine. According to an operation continuation time, additional values corresponding to the nozzle heating temperature may be accumulated. When the accumulation value is not more than a predetermined value, it is determined that the engine is in the initial period.

[0031] FIG. 3 shows a change in the injection deviation amount from the injector corresponding to a traveling distance, and a learning control effect. As shown in FIG. 3, each time the traveling distance reaches a predetermined distance, the controller 30 determines that the learning timing has been attained, and executes the learning control with the learning timing.

[0032] In the learning control, during non-injection operation, in which a command injection amount of the internal combustion engine is zero or less, the controller 30 executes learning injection (single-shot injection) from the injector. A generation torque is calculated based on the fluctuation amount of the RPM of the internal combustion engine, which has been increased through the learning injection, and the RPM of the internal combustion engine. The actual injection amount is estimated from the generation torque calculated. A deviation amount is obtained from the difference between the estimated actual injection amount and the command injection amount of the learning injection. This deviation amount is used in calculating a correction amount.

[0033] In FIG. 3, a line A1 indicates the deviation amount in the situation where the correction of the injection amount of the injector through the learning control is not executed. The line A1 substantially coincides with the deviation amount in the first half of the initial period shown in FIG. 2. In FIG. 3, a line B1 indicates the deviation amount in the case where the injection deviation amount of the injector is corrected through the above-mentioned learning control with the learning timing. Each time the learning control is performed, the deviation amount is reduced to a level G1. The level G1 corresponds, for example, to an error in the correction amount obtained through the learning control.

[0034] As indicated by the graph B1 of FIG. 3, when the learning control is consistently executed, it is possible to appropriately correct the deviation amount of the injector. However, if the learning timing has been attained, the learning control is not always executed. For, in a conventional learning control, a determination of the execution condition is made before it is determined that the learning timing has been attained and the learning control is performed. In the determination of the execution condition, it is determined whether the learning control may be executed or not. The controller is programmed so as not to execute the learning control in the case where the execution condition is not satisfied, for example, an environment in which the combustion of the injected fuel is not stable.

[0035] The learning control is a very effective means for correcting the injection deviation amount of the injector. However, if an erroneous learning control should be performed, it is impossible to make an effective correction until the next learning timing. Thus, the determination of the execution condition is somewhat strict. For example, when a short-range operation in which the warming-up operation is not completed is repeated, there is a possibility of a circulating water temperature, etc. not satisfying the execution condition. Thus, even if the learning timing has been attained, there is the possibility of continuation in a state in which the learning control is not executed. In the fuel injection amount learning method for the internal combustion engine according to the present invention, even when such a state continues and the execution condition is appropriately satisfied as described below, it is possible to execute the learning control.

[0036] In a first embodiment of the learning method shown in FIG. 4, the learning control is executed during the initial period. As can be seen from FIG. 2, during the initial period, the deviation amount of the injection amount of the injector is large. In the first embodiment, in order to ensure execution of the learning control, imprecision in the correction amount is allowed so long as it is within the permissible range, and the learning control is executed.

[0037] For example, the controller 30 executes a processing of a flowchart in FIG. 4 at each predetermined period of time (which, for example, is several ms to several hundred ms).

[0038] In step S10, the controller 30 determines whether or not it is the learning timing. When it is the learning timing (YES in step S10), the procedure advances to step S11. When it is not the learning timing (NO in step S10), the processing is completed. The controller 30 determines that it is the learning timing when, for example, the traveling distance from the previous learning timing has reached a predetermined distance.

[0039] In step S11, the controller 30 determines whether or not it is within the initial period. When it is determined that it is within the initial period (YES in step S11), the procedure advances to step S12. When it is determined that it is not within the initial period, the procedure advances to step S14A. Step S11 corresponds to an initial period determination step in which it is determined whether or not the accumulation time from the brand-new state of the injector is within a predetermined period of time.

[0040] In step S12, the controller 30 determines whether or not the execution frequency of the learning control has attained a predetermined frequency. When it is determined that the predetermined frequency has been attained (YES in step S12), the procedure advances to step S14A. When it is determined that the predetermined frequency has not been attained (NO in step S12), the procedure advances to step S14B. When, for example, the learning has been executed with the previous learning timing, it is determined that the predetermined frequency has been attained. Alternatively, when a state in which, although the learning timing has been attained, the learning control is not executed because of the execution condition not being satisfied, occurs N times in succession (N is an integer), it is determined that the predetermined frequency has not been attained. It is possible to employ various methods in determining whether or not the execution frequency of the learning control has attained the predetermined frequency. Step 12 corresponds to the learning frequency determination step.

[0041] In step S14A, the controller 30 prepares threshold values equivalent to that of the conventional execution condition determination. The controller 30 substitutes a threshold value W1 equivalent to that of the conventional determination for a water temperature threshold value Sw used for the determination of the circulating water temperature. A threshold value P1 equivalent to that of the conventional determination is substituted for an atmospheric pressure threshold value Sp used for the determination of the atmospheric pressure. A threshold value A1 equivalent to that of the conventional determination is substituted for an intake air temperature threshold value Sa used for the determination of the intake air temperature. A threshold value F1 equivalent to that of the conventional determination is substituted for a fuel temperature threshold value Sf used for the determination of the fuel temperature. The procedure advances from step S14A to step S22.

[0042] In step S14B, the controller 30 changes the threshold values for the conventional execution condition determination to threshold values making the execution condition less strict. The controller 30 substitutes a threshold value W2 less strict than that in the prior art for the water temperature threshold value Sw used for the determination of the circulating water temperature. A threshold value P2 less strict than that in the prior art may be substituted for the atmospheric pressure threshold value Sp used for the determination of the atmospheric pressure. A threshold value A2 less strict than in the prior art may be substituted for the intake air temperature threshold value Sa used for the determination of the intake air temperature. A threshold value F2 less strict than in the prior art may be substituted for the fuel temperature threshold value Sf used for the determination of the fuel temperature. The procedure advances from step S14B to step S22. For example, when the conventional threshold value W1 substituted for the water temperature threshold value Sw is 80°C, the relieved threshold value W2 is 60°. Step S14B corresponds to the learning frequency increase step in which the learning control execution frequency is forcibly increased.

[0043] Steps S22 to S28 correspond to the learning condition determination step in which it is determined whether or not the learning control execution condition is satisfied with the learning control execution timing.

[0044] In step S22, the controller 30 determines whether or not the circulating water temperature is or more than the water temperature threshold value Sw. The circulating water temperature is detected based on the detection signal from the circulating water temperature detection sensor 22. When the circulating water temperature is equal to or greater than the water temperature threshold value Sw (i.e., YES in step S22), the procedure advances to step S24. When the circulating water temperature is less than the water temperature threshold value Sw (NO in step S22), the processing is completed.

[0045] In step S24, the controller 30 determines whether or not the atmospheric pressure is equal to or greater than the atmospheric pressure threshold value Sp. The atmospheric pressure is detected based on the detection signal from the atmospheric pressure sensor 23. When the atmospheric pressure is equal to or greater than the atmospheric pressure threshold value Sp (YES in step S24), the procedure advances to step S26. When the atmospheric pressure is less than the atmospheric pressure threshold value Sp (NO in step S24), the processing is completed.

[0046] In step S26, the controller 30 determines whether or not the detected intake air temperature is equal to or greater than the intake air temperature threshold value Sa. The intake air temperature is measured based on the detection signal from the intake air temperature sensor 24. When the temperature of the intake air is equal to or greater than the intake air temperature threshold value Sa (YES in step S26), the procedure advances to step S28. When the temperature of the intake air is less than the intake air temperature threshold value (NO in step S26), the processing is completed.

[0047] In step S28, the controller 30 determines whether or not the fuel temperature is equal to or greater than the fuel temperature threshold value Sf. The fuel temperature is detected based on the detection signal from the fuel temperature sensor 25. When the fuel temperature is or more than the fuel temperature threshold value Sf (i.e., YES in step S28), the procedure advances to step S30. When the fuel temperature is less than the fuel temperature threshold value Sf (NO in step S28), the processing is completed.

[0048] In step S30, the controller 30 executes the learning control on the injection amount of the injector, and obtains the correction amount by which the deviation amount is to be corrected before completing the processing. The details of the learning control are as described above. Step S30 corresponds to the learning execution step in which the learning control is executed when it is determined that the execution condition (steps S22 to S28) is satisfied.

[0049] In the first embodiment shown in FIG. 4, when, within the initial period, the execution frequency of the learning control has not attained a predetermined frequency, the threshold value of the execution condition determined in steps S22 to S28 is forcibly changed such that the determination of the execution condition is relieved. As a result, even if an operation not easily allowing execution of the learning control, such as short-range operation, is repeated, it is possible to appropriately perform the learning control to obtain an appropriate correction amount for the injector.

[0050] FIG. 5 shows a change in the injection deviation amount from the injector and the effect of the learning control with respect to the traveling distance. In FIG. 5, the line A1 indicates the deviation amount when the correction of the injection amount of the injector through the learning control is not conducted. The line B1 indicates the deviation amount as corrected through the learning control by using the threshold values in step S14A. The line B2 indicates the deviation amount as corrected through the learning control by using the threshold values in step S14B. With regards to line B1, the deviation amount is reduced to a level G1 each time the learning control is conducted. With regards to line B2, the deviation amount is reduced to a level G2 (G2 > G1) each time the learning control is conducted. With regards to B2, the execution condition threshold value is less strict than in the case of the line B1. Thus, G2 > G1, results in a decreased precision in the correction amount of the learning result. Of course, the level G2 is also within the permissible range.

[0051] As is shown in FIG. 5, when the threshold values are lowered in step S14B of line B2, it is difficult to make the deviation amount smaller than that compared to line B1 in which the threshold values of step S14A are used. However, as indicated by the graph B2, it is possible to make the deviation amount smaller than in the case of the graph A1.

[0052] Instead of the first embodiment shown in FIG. 4, it is also possible to adopt a second embodiment shown in FIG. 7. In the first embodiment, when the learning frequency has not attained a predetermined frequency, the threshold value used for the determination of the execution condition is forcibly lessened. As a result, the learning control is executed, with the precision of the correction amount of the learning result being somewhat lowered. Of course, the precision of the correction amount is within the permissible range. In contrast, in the second embodiment, it is possible to appropriately widen the determination of the learning execution condition to make it possible to increase the learning frequency, without lowering the precision of the correction amount of the learning result. The second embodiment will be described with reference to FIGS. 6 and 7.

[0053] In FIG. 6, a horizontal axis indicates an injection pressure of the fuel from the injector. A vertical axis indicates a height image of learning control execution condition threshold values such as circulating water temperature and atmospheric pressure. In the internal combustion engine, there are cases in which the fuel injection pressure is changed with respect to an operational condition. As the injection pressure increases, the learning control execution condition threshold values also increase. In FIG. 6, a borderline L indicates limit a permissible area of the threshold value with respect to the fuel injection pressure. For example, in the case where the fuel injection pressure is a pressure Ph, it is only necessary for the threshold value to be Th or more.

[0054] Suppose, for example, the fuel injection pressure up to a pressure Pg refers to the range of pressures within which learning control is possible. In the case of the conventional learning control execution condition, the learning control is executed within the range R1 so that the determination of the learning control execution condition may be appropriate under any pressure within the injection pressure learning capability range. For example, in the case where the fuel injection pressure is the pressure Ph, the threshold value is not set to Th but rather to Tg. That is, the proper learning control execution permissible range is the range R1 + the range R2. However, in the conventional learning control, the learning control execution condition is determined only in the range R1, and the execution condition threshold value is not set in an optimum manner.

[0055] In the second embodiment, the threshold values to be used for the determination of the learning control execution condition are optimized with respect to the fuel injection pressure. As a result, the learning control capability range is enlarged from the range R1 only to the range R1 + the range R2. In this way, the learning frequency can be increased.

[0056] The second embodiment shown in FIG. 7 has steps S22 to S30 which are the same as those of the first embodiment shown in FIG. 4, and steps S10 to S18 which differ from those of the first embodiment.

[0057] In step S10 of FIG. 7, the controller 30 determines whether or not it is the learning timing. When it is the learning timing for the fuel injection amount (YES in step S10), the procedure advances to step S16. When it is not the learning timing (NO in step S10), the processing is completed. As in, for example, the first embodiment, the controller 30 determines that it is the learning timing when the traveling distance from the previous learning timing has attained a predetermined distance.

[0058] In step S16, the controller 30 detects the fuel pressure and the procedure advances to step S18. The fuel pressure is used by the controller 30 during the execution of the learning control.

[0059] In step S18, the controller 30 obtains a threshold value Wn for determination of a circulating water temperature with regards to a fuel pressure detected from a map or the like. The obtained threshold value Wn is substituted for a water temperature threshold value Sw. A threshold value Pn for determination of an atmospheric pressure with regards to the fuel pressure detected is obtained from a map or the like. The obtained threshold value Pn is substituted for an atmospheric pressure threshold value Sp. The controller 30 obtains a threshold value An for the determination of an intake air temperature with respect to the fuel pressure detected from a map or the like. The obtained threshold value An is substituted for an intake air temperature threshold value Sa. The threshold value Fn for the determination of a fuel temperature with regards to the fuel pressure detected is obtained from a map or the like. The obtained threshold value Fn is substituted for a fuel temperature threshold value Sf, and the procedure advances to step S22. As described above, each threshold value corresponding to the borderline shown in FIG. 6 is fixed.

[0060] Step S16 and step S18 correspond to the learning frequency increase step. The processing from step S22 onward is the same as that in the first embodiment, so a description thereof will be left out.

[0061] In the prior art, the range where the learning control execution condition is satisfied is only in the range R1 of FIG. 6. On the other hand, in the second embodiment, the threshold values are changed appropriately with regards to the fuel injection pressure. As a result, in the second embodiment, the range where the learning control execution condition is satisfied is enlarged from mere the range R1 to the range R1 + the range R2 of FIG. 6. Thus, it is possible to increase the learning control frequency as compared with the prior art while securing a precision equivalent to that in the prior art for the correction amount for the injector through the learning control. In some cases, an operation not easily allowing execution of the learning control, such as short-range operation, is repeated. Even in such cases, it is possible to appropriately perform the learning control to obtain an appropriate correction amount for the injector.

[0062] Instead of the first embodiment, it is also possible to adopt a third embodiment, which is a combination of the first embodiment and the second embodiment. In the third embodiment, instead of step 14A of the first embodiment shown in FIG. 4, the processing of step S16 and S18 shown in FIG. 7 is executed to set each threshold value corresponding to the borderline L shown in FIG. 6. In step S18, each threshold value is set so as to be somewhat below the borderline L shown in FIG. 6 so that each threshold of the execution condition determination is lessened. Thus, the third embodiment provides similar effects as that of the first embodiment and the second embodiment.

[0063] While the embodiments of invention have been described with reference to specific configurations, it will be apparent to those skilled in the art that many alternatives, modifications and variations may be made without departing from the scope of the present invention. Accordingly, embodiments of the present invention are intended to embrace all such alternatives, modifications and variations that may fall within the spirit and scope of the appended claims. For example, embodiments of the present invention should not be limited to the representative configurations, but may be modified, for example, as described below.

[0064] The control system for executing the learning method according to the present invention may be applied to the embodiment as shown in FIG. 1, and may also be applied to various internal combustion engines in which fuel is injected from an injector.

[0065] As described above, in the learning control execution condition, the threshold values of the circulating water temperature, the atmospheric pressure, the intake air temperature, and the fuel temperature may all be changed. Alternatively, it is also possible to change only two factors in the threshold values; for example, the circulating water temperature and the atmospheric pressure. Alternatively, it is also possible to change the threshold value of one or more of the factors: the circulating water temperature, the atmospheric pressure, the intake air temperature, and the fuel temperature.

[0066] In the above description, the inequality signs > and < ("greater than" and "less than", respectively) may be replaced by the ≥ and ≤ ("greater than or equal to" and "less than or equal to", respectively) signs. Alternatively, in some of the embodiments, there exists the possibility that only one of the inequality signs will be replaced.

[0067] The values used in the description of the embodiment are only given by way of example and should not be construed restrictively.

[0068] A learning method for an internal combustion engine (10) may include steps as follows. Injection for learning is executed from an injector (43A to 43D) during non-injection operation of the engine (10) with a timing. A correction amount for the injector (43A to 43D) is obtained based on an RPM fluctuation amount of the engine (10) due to the injection for learning and on the RPM of the engine (10). A controller (30) determines whether or not a learning control execution condition is satisfied with a predetermined condition with the timing. The controller (30) executes the learning control when the learning control execution condition is satisfied with the predetermined condition. The controller (30) obtains an execution frequency of the learning control. The controller (30) forcibly increases the execution frequency of the learning control when the execution frequency obtained in a previous step has not attained a predetermined frequency.

Claims

1. A fuel injection amount learning method for an internal combustion engine (10) in which injection for learning is executed from an injector (43A to 43D) during non-injection operation of the internal combustion engine (10), and learning control, in which a correction amount for the injector (43A to 43D) is obtained based on an RPM fluctuation amount of the internal combustion engine (10) due to the injection for learning and on the RPM of the internal combustion engine (10), is executed with a timing, the method comprising the steps of:

    determining whether or not a learning control execution condition is satisfied with a predetermined condition with the timing by a controller (30),
    executing the learning control by the controller (30) when the learning control execution condition is satisfied with the predetermined condition,
    obtaining an execution frequency of the learning control by the controller (30), and
    forcibly increasing the execution frequency of the learning control by the controller (30) when the execution frequency obtained in a previous step has not attained a predetermined frequency.

2. The fuel injection amount learning method of claim 1, wherein in the step of increasing the execution frequency of the learning control, the controller (30) changes a threshold value (Sw, Sp, Sa, Sf) of the predetermined condition according to a fuel injection pressure from the injector (43A to 43D).

3. The fuel injection amount learning method of claim 1, further comprising the steps of:

    determining whether or not an accumulation period from a brand-new state of the injector (43A to 43D) is within a predetermined initial period by the controller (30), and
    changing a threshold value (Sw, Sp, Sa, Sf) of the predetermined condition so as to relieve the learning control execution condition by the controller (30) when the accumulation period is with-

in the predetermined initial period and while the execution frequency has not attained the predetermined frequency.

4. The fuel injection amount learning method of claim 2 or claim 3, wherein the predetermined condition includes a threshold value (Sw) of a circulating water temperature of the internal combustion engine (10) and a threshold value (Sp) of an atmospheric pressure.

5. The fuel injection amount learning method of claim 2 or claim 3, wherein the predetermined condition includes a threshold value (Sw) of a circulating water temperature of the internal combustion engine (10) as the threshold value (Sw, Sp, Sa, Sf), a threshold value (Sp) of an atmospheric pressure as the threshold value (Sw, Sp, Sa, Sf), a threshold value (Sa) of a temperature of intake air of the internal combustion engine (10) as the threshold value (Sw, Sp, Sa, Sf), and a threshold value (Sf) of a fuel temperature as the threshold value (Sw, Sp, Sa, Sf).

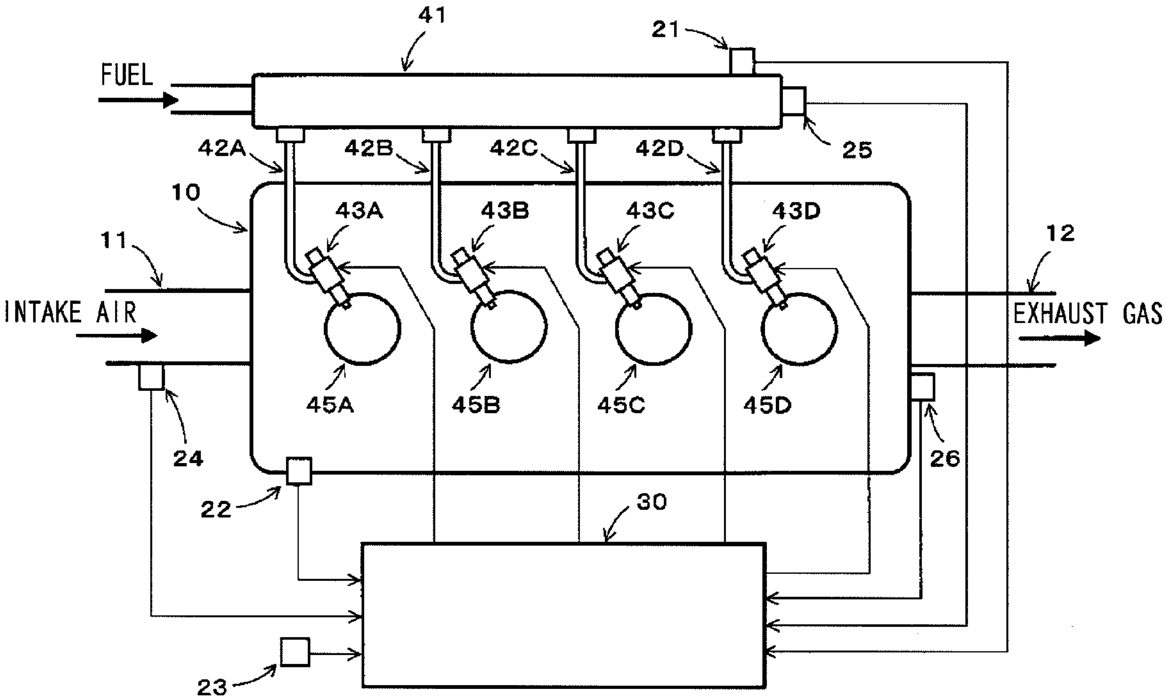
41
21
FUEL
25
42A
42B
42C
42D
10
43A
43B
43C
43D
11
12
INTAKE AIR
EXHAUST GAS
45A
45B
45C
45D
24
26
22
30
23

FIG. 1

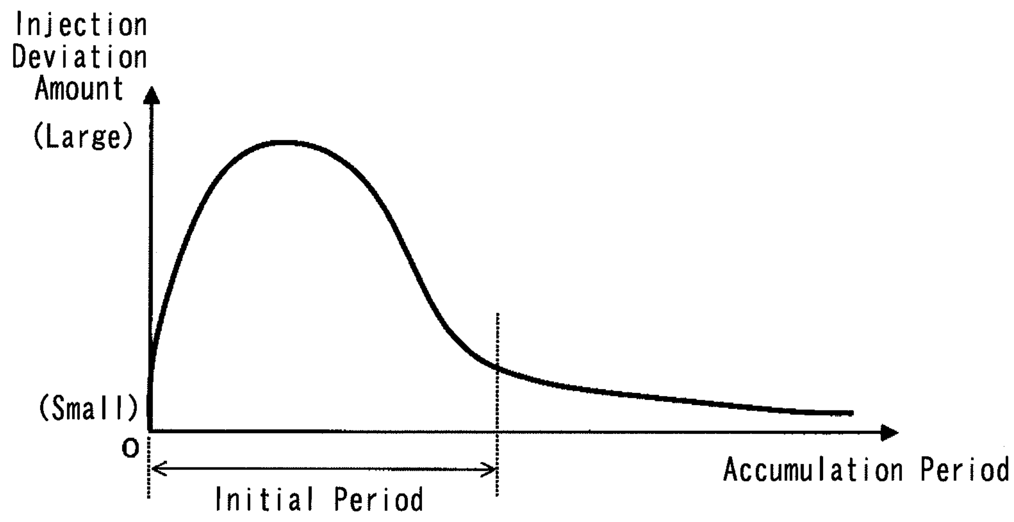
Injection
Deviation
Amount
(Large)
(Small)
O
Initial Period
Accumulation Period

FIG. 2

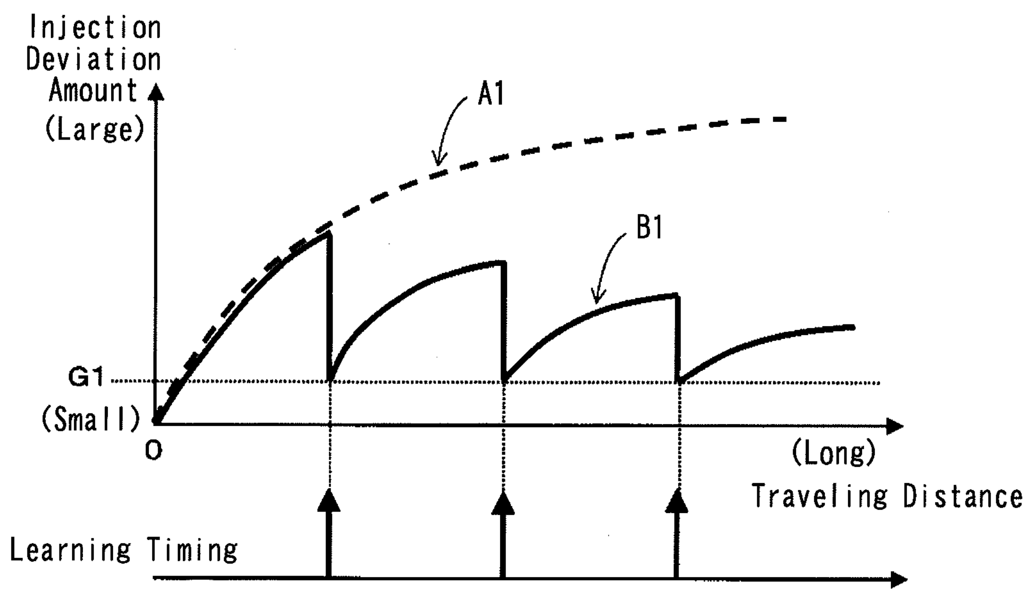
Injection
Deviation
Amount
(Large)
A1
B1
G1
(Small)
O
(Long)
Traveling Distance
Learning Timing

FIG. 3

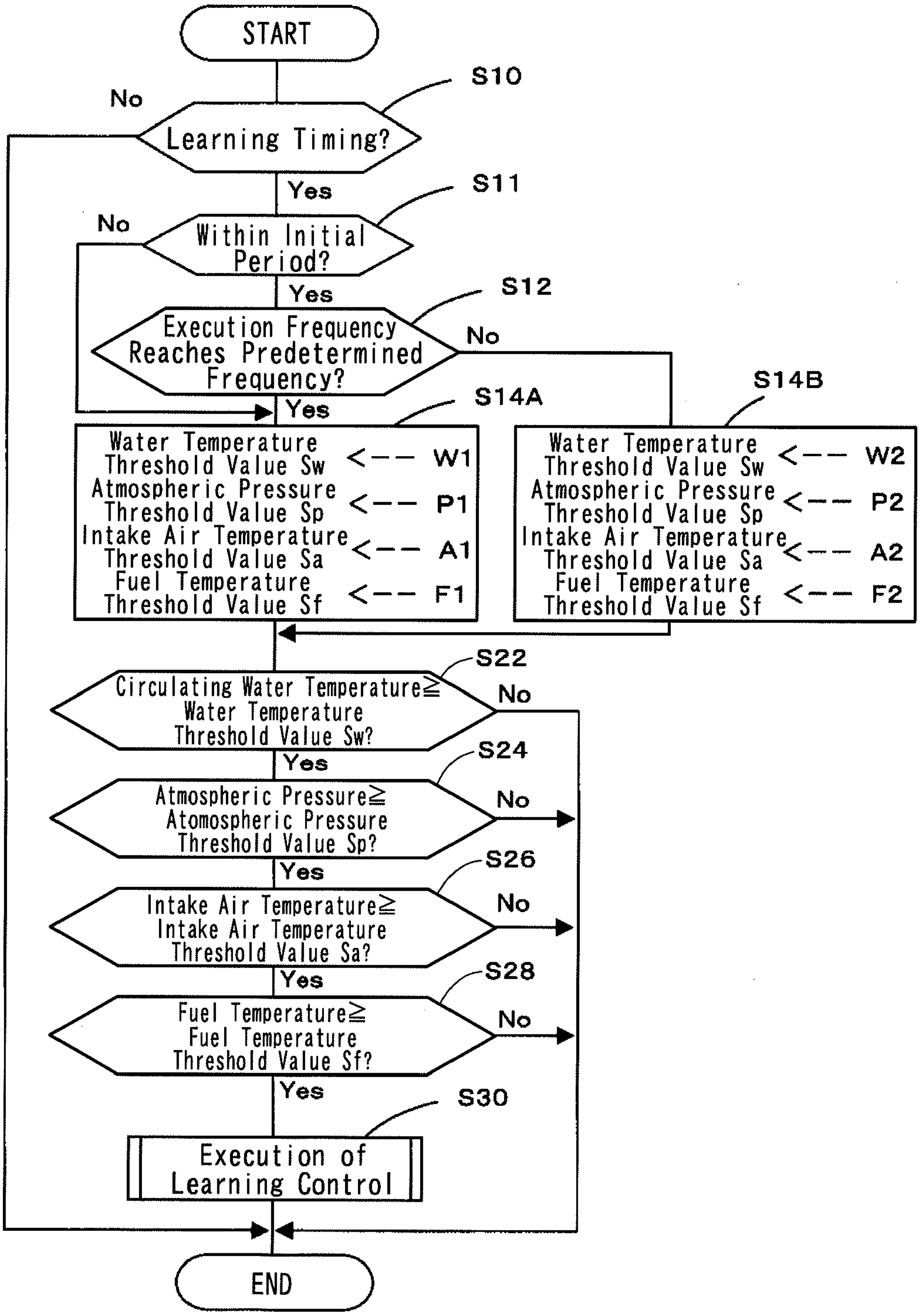
START
S10
No
Learning Timing?
Yes
S11
No
Within Initial Period?
Yes
S12
Execution Frequency Reaches Predetermined Frequency?
No
Yes
S14A
S14B
Water Temperature Threshold Value Sw <-- W1
Atmospheric Pressure Threshold Value Sp <-- P1
Intake Air Temperature Threshold Value Sa <-- A1
Fuel Temperature Threshold Value Sf <-- F1
Water Temperature Threshold Value Sw <-- W2
Atmospheric Pressure Threshold Value Sp <-- P2
Intake Air Temperature Threshold Value Sa <-- A2
Fuel Temperature Threshold Value Sf <-- F2
S22
Circulating Water Temperature≧ Water Temperature Threshold Value Sw?
No
Yes
S24
Atmospheric Pressure≧ Atomospheric Pressure Threshold Value Sp?
No
Yes
S26
Intake Air Temperature≧ Intake Air Temperature Threshold Value Sa?
No
Yes
S28
Fuel Temperature≧ Fuel Temperature Threshold Value Sf?
No
Yes
S30
Execution of Learning Control
END

FIG. 4

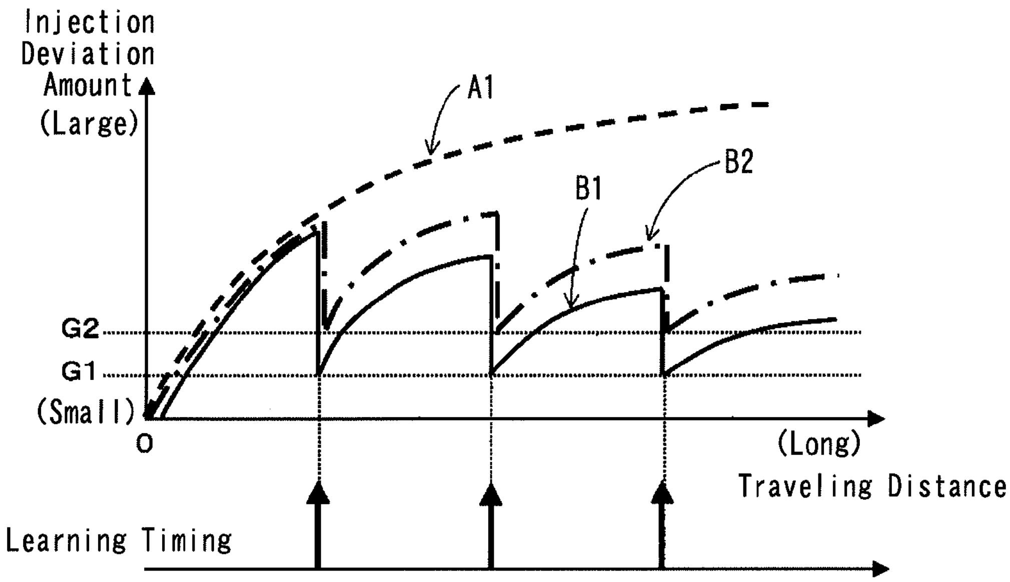
Injection
Deviation
Amount
(Large)
A1
B2
B1
G2
G1
(Small)
O
(Long)
Traveling Distance
Learning Timing

FIG. 5

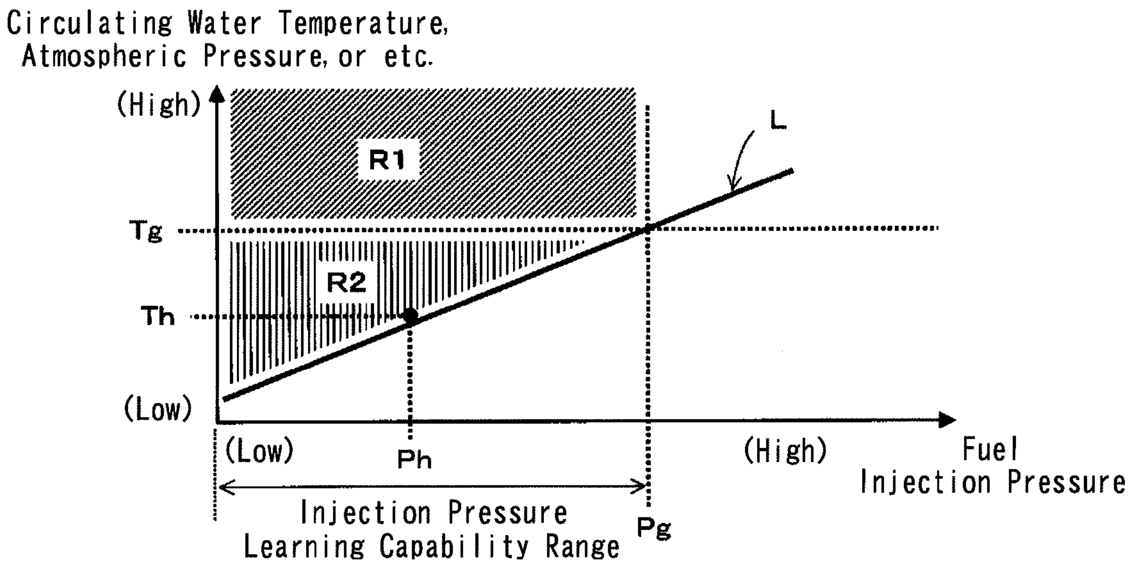
Circulating Water Temperature,
Atmospheric Pressure, or etc.
(High)
R1
L
Tg
R2
Th
(Low)
(Low)
Ph
(High)
Fuel
Injection Pressure
Injection Pressure
Learning Capability Range
Pg

FIG. 6

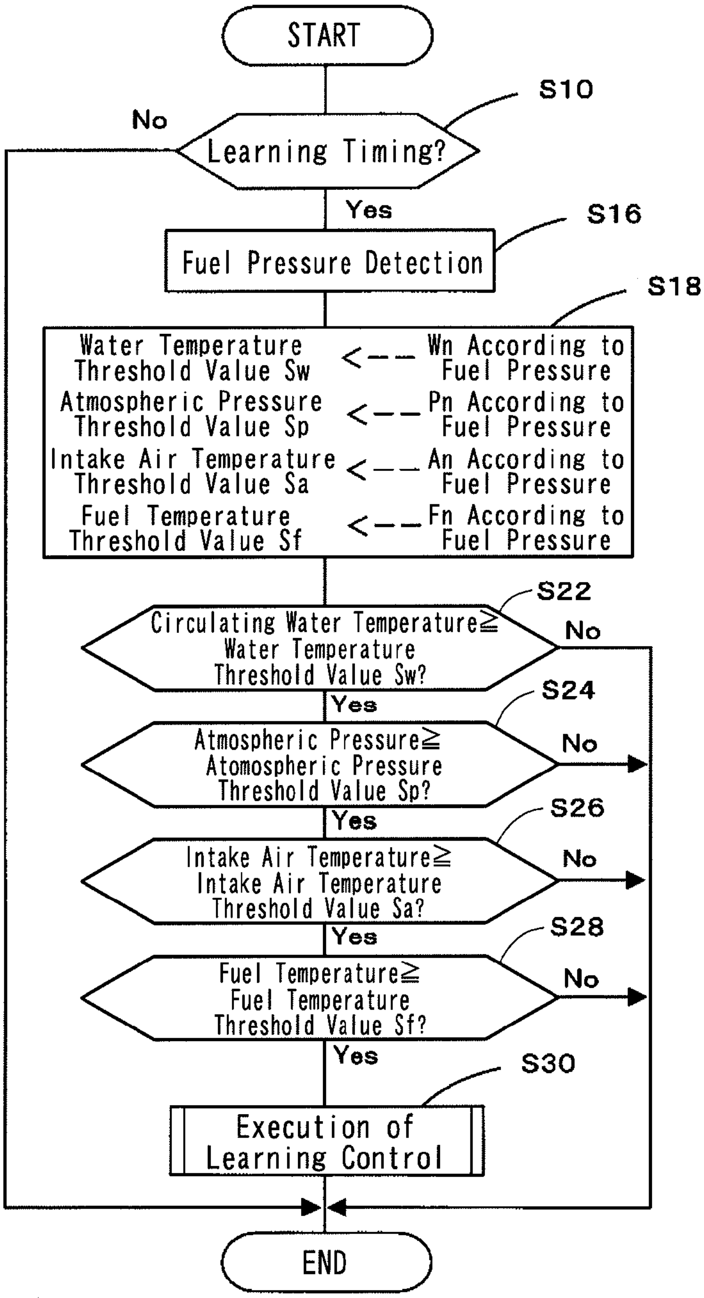
START
S10
No
Learning Timing?
Yes
S16
Fuel Pressure Detection
S18
Water Temperature Threshold Value Sw <--- Wn According to Fuel Pressure
Atmospheric Pressure Threshold Value Sp <--- Pn According to Fuel Pressure
Intake Air Temperature Threshold Value Sa <--- An According to Fuel Pressure
Fuel Temperature Threshold Value Sf <--- Fn According to Fuel Pressure
S22
Circulating Water Temperature≧ Water Temperature Threshold Value Sw?
No
Yes
S24
Atmospheric Pressure≧ Atomospheric Pressure Threshold Value Sp?
No
Yes
S26
Intake Air Temperature≧ Intake Air Temperature Threshold Value Sa?
No
Yes
S28
Fuel Temperature≧ Fuel Temperature Threshold Value Sf?
No
Yes
S30
Execution of Learning Control
END

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 3679

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A	* paragraphs [0056] - [0058], [0080] - [0103]; figures 1,5,6,17,21,22 *	2-5	
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F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	22 November 2013	Ossanna, Luca

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2
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			JP	4089244	B2	28-05-2008
			JP	2003254139	A	10-09-2003
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			JP	2008014152	A	24-01-2008
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			JP	2009264165	A	12-11-2009

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