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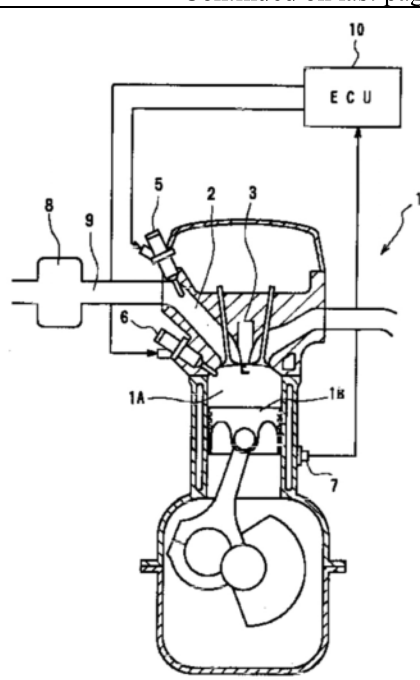
(54) [Title of Invention] FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINE

(57) [Abstract]
[Problem] The present invention relates to a fuel injection apparatus for an internal combustion engine that is capable of reliably suppressing knocking without causing a decrease in output.
[Resolution Means] If knocking is detected by a knock detection means 7, fuel is injected from both fuel injection valves in a first fuel injection valve 5 provided in an intake passage 2 and a second fuel injection 6 valve for injecting fuel directly into a combustion chamber. Thus, when knocking actually occurs, it is reliably switched to an appropriate fuel injection mode, and knocking is suppressed without causing a decrease in output.



[Scope of Claims]
What is claimed is:
[Claim 1] A fuel injection apparatus for an internal combustion engine, comprising:
a first fuel injection valve provided in an intake passage,
a second fuel injection valve for injecting fuel directly into a combustion chamber, and
a knock detection means for detecting knocking, wherein:
if knocking is detected by the knock detection means, fuel is injected from both fuel injection valves in the first fuel injection valve provided in the intake passage and the second fuel injection valve for injecting fuel directly into the combustion chamber.
[Claim 2] The fuel injection apparatus for an internal combustion engine according to claim 1, wherein if knocking is detected by the knock detection means, fuel of an amount such that the air to fuel ratio is about 30 to 60 is injected from the first fuel injection valve during intake stroke, and fuel of an amount such that the total air to fuel ratio is stoichiometric or rich is injected from the second fuel injection valve during compression stroke.
[Detailed Description of the Invention]
[0001]
[Technical Field of the Invention] The present invention relates to a fuel injection apparatus for an internal combustion engine suitable for use in an internal combustion engine that injects fuel into an intake passage.
[0002]
[Prior Art] Generally, in an engine, as shown in FIG. 6(B), the higher the temperature of the combustion chamber or the higher the pressure of the combustion chamber, the more easily the fuel self-ignites, and the engine is more susceptible to knocking. Furthermore, as shown in FIG. 6(A), the self-ignition region also depends on the air to fuel ratio, and if the air to fuel ratio is too high, the air to fuel mixture is too lean to be able to self-ignite, and furthermore, if the air to fuel ratio is too low, then the mixture will be too rich and will also not self-ignite. In contrast to this, knocking is likely to occur in the region of an air to fuel ratio of about 12 to 18.
[0003] Furthermore, at low engine speeds, the mixture is exposed to a high temperature combustion chamber wall for a long time, the mixture temperature rises, so it is easy to self-ignite, therefore it is extremely prone to knocking under low speed and high load conditions. Conventionally, when such knocking occurs, it is common to suppress the knocking by retarding the ignition timing, but when the ignition timing is retarded a decrease in output cannot be avoided.
[0004] Incidentally, Patent No. 2668680 discloses a technique that controls knocking without decreasing output, wherein a fuel injection mode only for in-cylinder injection, a fuel injection mode combining in-cylinder injection and intake injection, and a fuel injection mode only for intake injection are appropriately switched according to the respective operating conditions in a spark ignition type in-cylinder direct injection type engine.
[0005]
[Problem to be Solved by the Invention] However, with such a technique, switching of the fuel injection mode is performed for each operation region set in advance, so it is not possible to accurately coordinate with the actual operation status. Furthermore, there have been cases where the pre-set operating region was incompatible with the actual engine due to manufacturing variations and the like of individual engines. For this reason, although knocking actually occurs, there is a possibility that the appropriate fuel injection mode cannot be set.
[0006] The present invention was devised in view of such a problem, therefore the object is to provide a fuel injection apparatus for an internal combustion engine that is capable of reliably suppressing knocking without causing a decrease in output.

[0007]
[Means for Solving the Problem] With the fuel injection apparatus of an internal combustion engine in the present invention according to claim 1, if knocking is detected by a knock detection means, fuel is injected from both fuel injection valves in a first fuel injection valve provided in an intake passage and a second fuel injection valve for injecting fuel directly into a combustion chamber.
[0008] Thus, when knocking actually occurs, it is reliably switched to the appropriate fuel injection mode, and knocking is suppressed without causing a decrease in output. Furthermore, in the fuel injection apparatus for an internal combustion engine of the present invention according to claim 2, if knocking is detected by the knock detection means, fuel with an air to fuel ratio of about 30 to 60 is injected from the first fuel injection valve during intake stroke, and fuel of an amount such that the total air to fuel ratio becomes stoichiometric or rich is injected from the second fuel injection valve during compression stroke.
[0009] Thus, a partially fuel-rich mixture by fuel injection from the second fuel injection valve flows into the combustion chamber in which a lean mixture (air to fuel ratio 30 to 60) formed in advance by fuel injection from the first fuel injection valve spreads within the cylinder. In this case, the mixture formed by fuel injection from the first fuel injection valve is sufficiently lean and does not self-ignite, and furthermore, the rich mixture formed by fuel injection from the second fuel injection valve does not self-ignite as there is no time for a pre-knock reaction to proceed before ignition with a spark plug after this. As a result, knocking is suppressed without causing the fuel to self-ignite. Furthermore, since the overall air to fuel ratio is stoichiometric or rich, a decrease in output is also suppressed.
[0010]
[Embodiments of the Invention] The fuel injection apparatus for an internal combustion engine according to one embodiment of the present invention will be described with reference to drawings below. FIG. 1 is a schematic view showing the main configuration thereof. In the present embodiment, the internal combustion engine (engine) is based on a general intake injection engine 1 that injects fuel into an intake passage and mixes intake and fuel, and particularly in the present embodiment, a multipoint injection type engine in which an injector (referred to as a first fuel injection valve or main injector) 5 is provided in the intake passage of each cylinder is applied.
[0011] Furthermore, in FIG. 1, 1A is a cylinder, 1B is a piston, and 2 is an intake passage. A surge tank 8 and an intake manifold 9 or the like are connected to the upstream side of the intake passage 2, and the intake passage 2 is configured to include the surge tank 8 and the intake manifold 9. Moreover, as shown in FIG. 1, the engine 1 has a spark plug 3 provided at the top of the combustion chamber, and it is configured as a spark ignition type engine in which fuel is ignited by ignition of this spark plug. Additionally, the engine 1 is provided with an injector (referred to as a second fuel injection valve or sub-injector) 6 with an injection hole preferably disposed in the combustion chamber so as to inject fuel directly into the combustion chamber.
[0012] This sub-injector 6 is an injector capable of injecting fuel at high pressure during the compression stroke, and fuel pressurized by a high-pressure pump (not illustrated) is supplied. On the other hand, the engine 1 is provided with a knock sensor (knock detection means) 7 that detects knocking when knocking occurs. A knock sensor that is a type that detects abnormal vibrations in the cylinder block of engine 1 is applied in the present embodiment as the knock sensor 7, yet a knock sensor that detects knocking based on rotational speed fluctuations of the engine in addition to this may also be used.
[0013] Information detected by the knock sensor 7 is to be input to an electronic control unit (ECU) 10, and the ECU 10 sets an operation control signal for each of the injectors 5 and 6

above based on information from the knock sensor 7. Also, in the present embodiment if it is determined by the ECU 10 that knocking has occurred based on detection information from the knock sensor 7, fuel injection is performed from the two injectors 5 and 6 to suppress this knocking. Note that the fuel injection mode that injects fuel from the two injectors 5 and 6 in this way will hereinafter be referred to as split injection mode, and furthermore, the operating state in which knocking occurs will be referred to as the specified operating state.

[0014] Furthermore, while in a normal operating state where knocking is not occurring, the operation of the sub-injector 6 is inhibited by the ECU 10 and switches to a fuel injection mode to the intake passage 2 with the main injector 5 (hereinafter referred to as intake pipe injection mode). As in the foregoing, in engine 1, the operation is performed by injecting fuel from the main injector 5 during normal operation, and while in the specified operation state where knocking is detected, fuel injection is performed from the two injectors 5 and 6 to suppress knocking.

[0015] Here, if knocking is detected, a small amount of fuel which cannot self-ignite is injected from the main injector 5 into the intake passage 2 while the remaining fuel is directly injected from the sub-injector 6 into the cylinder (combustion chamber) during the compression stroke. Specifically, while in this split injection mode, the fuel injection amount is set so that a stoichiometric or rich mixture (that is, a mixture whose total air to fuel ratio is the theoretical air to fuel ratio or is smaller than the theoretical air to fuel ratio) is formed due to the total injection amount of intake pipe injection and in-cylinder direct injection.

[0016] In this case, as for fuel injection timing, intake pipe injection with the main injector 5 is performed during the exhaust stroke or intake stroke (preferably exhaust stroke in which the fuel atomization time in the intake pipe can be lengthened), and in-cylinder direct injection with the sub-injector 6 is performed during the compression stroke. Although in-cylinder direct injection with the sub-injector 6 is performed after intake pipe injection with the main injector 5 is performed, fuel supplied into the cylinder by intake pipe injection self-ignites which promotes knocking, therefore during intake pipe injection, fuel injection of an amount where fuel concentration is lean is performed so that the injected fuel does not self-ignite.

[0017] That is, as shown in FIG. 6(A), for example, when the air to fuel ratio A/F is about 18 to 12 in the vicinity of the theoretical air to fuel ratio, the fuel is likely to self-ignite, but the fuel is less likely to self-ignite as the fuel concentration of the mixture deviates from being in the vicinity of the theoretical air to fuel ratio. In order to apply fumigation, it is necessary to mix fuel into the intake to the extent that the mixture does not cause self-ignition while atomizing or evaporating the fuel in the intake stroke, therefore it is sufficient to create a mixture with an extremely lean fuel concentration (air to fuel ratio A/F is significantly larger than in the vicinity of the theoretical air to fuel ratio) by intake pipe injection. Note that fumigation means that fuel is mixed into the intake to such an extent that the mixture does not cause self-ignition while atomizing or evaporating the fuel during the intake stroke in a diesel engine, shortening the ignition delay with a pre-flame reaction during the compression stroke to prevent knocking. Conventional fumigation could only be applied to diesel engines, but it is now possible to implement the same technique in spark ignition engines.

[0018] Also, here at the time of intake pipe injection, fuel injection is performed by setting the injection amount so that the air to fuel ratio becomes about 30 to 60. On the other hand, fuel is directly injected from the sub-injector 6 so that the fuel becomes a stoichiometric or rich mixture due to the total injection amount of in-cylinder direct injection and intake pipe injection. In the present embodiment, in order to be able to form an air to fuel mixture having a total air to fuel ratio of about 12, fuel injection is performed by setting an injection amount corresponding to an air to fuel ratio of approximately 15 to 20 during in-cylinder direct injection.

[0019] That is, if the air to fuel ratio at the time of intake pipe injection is about 60, and if fuel injection is performed with an injection amount corresponding to the air to fuel ratio of about 15 at the time of in-cylinder direct injection, the total air to fuel ratio according to the total injection amount can be set to about 12 (that is, 1/12 = 1/60 + 1/15). If the air to fuel ratio at the time of intake pipe injection is about 30, and if fuel injection is performed with an injection amount corresponding to the air to fuel ratio of about 20 at the time of in-cylinder direct injection, the total air to fuel ratio according to the total injection amount can be set to about 12 (that is, 1/12 = 1/30 + 1/20).
[0020] Also, as mentioned above, this kind of split injection mode is implemented if it is determined by the ECU 10 that the engine 1 is in the specified operation state (that is, where knocking is occurring) based on detection information from the knock sensor 7, and furthermore, the engine 1 operates by general premixed combustion due to fuel injection from the main injector 5 during normal operation where knocking does not occur.
[0021] Here, when describing the action of knock suppression with this kind of split injection, during in-cylinder direct injection, as shown in FIG. 2(A), a partially fuel-rich mixture (air to fuel mixture having a high fuel concentration since a fuel corresponding to the total air to fuel ratio A/F = 15 to 20 is injected) by in-cylinder injection forms a laminar flow within the combustion chamber in which a lean mixture (air to fuel ratio A/F = 30 to 60) formed in advance by fuel injection spreads, and flows in the vicinity of the spark plug 3.
[0022] In this case, the mixture formed by intake pipe injection from the main injector 5 is sufficiently lean and does not self-ignite, and furthermore, the rich mixture formed so as to form a laminar flow by in-cylinder direct injection from the sub-injector 6 does not self-ignite as there is no time for a pre-knock reaction to proceed before ignition with the spark plug 3 after this. It is conceivable that this is the effect of suppressing knocking with split injection, and as a result, ignition is performed by the spark plug 3 without causing self-ignition of fuel.
[0023] As a result, first, the rich mixture in the vicinity of the spark plug 3 is ignited, and the rich mixture forming a laminar flow begins combustion. Since this rich mixture causes a lack of air during combustion, a large amount of soot is produced due to combustion, yet as shown in FIG. 2(B), the lean mixture formed by intake pipe injection is presumed to combust with this generated soot as the ignition source.
[0024] That is, the lean mixture formed by the intake pipe injection effectively utilizes the surplus air around the layered rich mixture formed by in-cylinder direct injection, and the combustion energy can be sufficiently increased and a large output can be obtained, and while a relatively rich mixture is combusted by stratified combustion with in-cylinder direct injection, the occurrence of soot in the combustion chamber, which is a problem, can be greatly suppressed.
[0025] Note that this split injection mode may be provided with an inhibition region. Here, this inhibition region is a region where the engine coolant temperature (it may be a detectable parameter corresponding to the engine temperature as well as the cooling water temperature, yet here it is an easily detectable cooling water temperature) is a specified temperature or less (for example, -10°C). This is because when the engine temperature is low, atomization of the fuel deteriorates, and when the fuel of intake pipe injection is difficult to atomize, the fumigation conditions are not satisfied, so there is a possibility that the knock prevention effect cannot be obtained.
[0026] Next, how to set the ratio of the injection amount and the injection timing for in-cylinder direct injection in such a split injection mode will be described with reference to FIGS. 3 and 4. Note that FIGS. 3 and 4 are each drawings that illustrate an example of the characteristics in a spark ignition in-cylinder injection type internal combustion engine having different specifications, and for each drawing, (A) is one that describes that engine rotation speed Ne, the ignition timing and the intake pipe injection timing are fixed to

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