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(54) **Fuel injection controller**

(57) In a fuel injection controller 100, a duration timer 19 measures an intertooth interval from when a pickup detects a tooth of a pulser to when it detects a next tooth. A calculation unit 15 specifies an injection timing for each cylinder by using the intertooth interval stored in a storage unit 18. The storage unit 18 renews the stored intertooth interval with a newly input intertooth interval of a tooth of

the same number as a tooth of the stored intertooth interval. When a determination unit 17 determines that the intertooth interval to be used for specifying the injection timing corresponds to an intertooth interval of a missing tooth zone 13a, the calculation unit 15 converts and uses the intertooth interval to be used based on the number of the tooth most recently detected by the pickup when the intertooth interval is used.

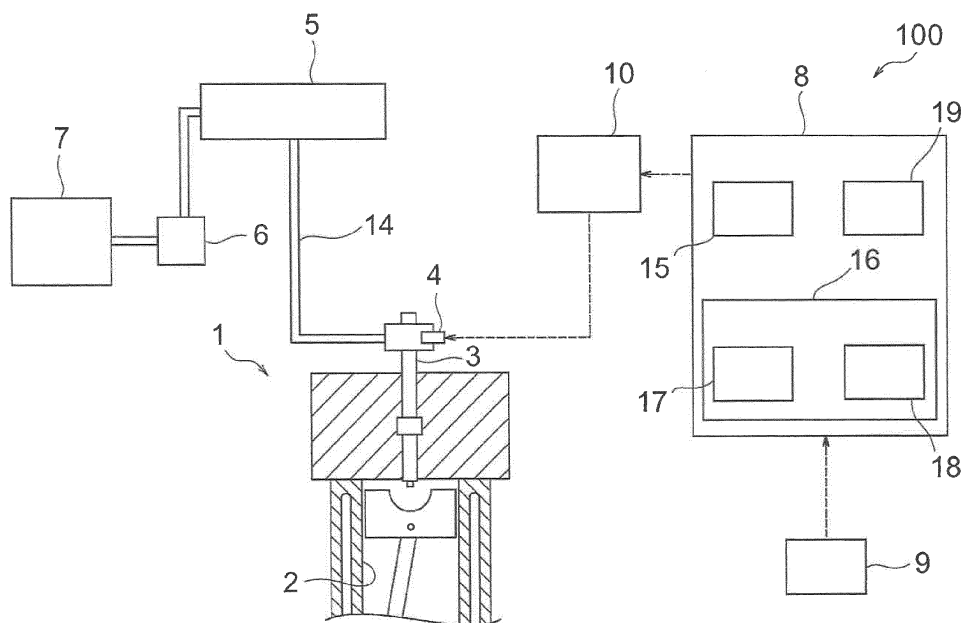


FIG.1

Description

BACKGROUND OF THE INVENTION

Field of the invention

[0001] The present invention relates to a diesel engine fuel injection controller.

Description of the Related Art

[0002] Common rail injection is the mainstream system of diesel engines today. A common rail diesel engine has a high degree of freedom in controlling injection, as multiple injections are made easy by the fuel injection controller that controls the energization time (valve open time) of injectors. The fuel injection controller calculates an optimal injection amount and injection timing for starting fuel injection in accordance with various running conditions of the diesel engine. The valves of the injectors are controlled to open and close in accordance with injection signals sent from the fuel injection controller. The injection timing calculated by the fuel injection controller is stored in a storage region referred to as an injection memory.

[0003] As shown in Japanese Patent Application Laid-open No. 2001-234777, injection timing is controlled based on calculation of crank angles in diesel engines. Crank angles are determined by detecting teeth formed at equal crank angles around the outer circumference of a disc-like pulser that rotates with the crankshaft. The injection memory stores a reference tooth that is the tooth immediately before the injection start crank angle determined as the injection timing angle, and an injection start interval, which is specified as a time determined from the angle difference between the reference tooth and the injection start crank angle based on the rotation speed. The fuel injection controller starts a timer when the reference tooth stored in the injection memory is detected, and when the injection start interval has elapsed, the controller transmits an injection signal to an injector.

[0004] To calculate the injection start interval or time specified by the angle difference for a cylinder, the rotation time of a tooth, corresponding to a reference tooth of the current cylinder, of the previous cylinder where fuel was injected immediately before, is used. The rotation time of the tooth is a period between detection of one tooth and detection of a next tooth detected by a tooth detector such as a pickup. The teeth on the pulser are divided into a plurality of sections corresponding to the respective cylinders, with numbers being assigned to the teeth in each section, and the rotation time of the detected tooth is stored in a rotation time storage region provided for each tooth number. When the rotation time of the same number tooth in the next section is detected, the value stored in the rotation time storage region is renewed with the new rotation time. For calculating the injection start interval, the rotation time stored in the rota-

tion time storage region for the same tooth number as that of the reference tooth is used.

[0005] The pulser formed with teeth includes a missing tooth portion in one of the sections to serve as a reference for determining crank angle. Incidentally, the missing tooth portion includes a tooth and missing teeth which follow the tooth. In the section where the missing tooth portion is present, the rotation time of the entire missing tooth portion from the tooth in the missing tooth portion to a tooth next to the missing tooth portion is stored and renewed in the rotation time storage region for the tooth number of the tooth in the missing tooth portion, and the rotation times for the tooth numbers which are missing due to the missing teeth in the section with the missing tooth portion, which are stored in the rotation time storage regions for these tooth numbers, are not renewed. Therefore, if, in a section following the section with the missing tooth portion, a tooth having a tooth number corresponding to one of the existing or missing teeth numbers in the missing tooth portion is determined as the reference tooth, the value in the rotation time storage region for the tooth number of the tooth in the missing tooth portion, in which the rotation time of the entire missing tooth portion is stored, is corrected before being used.

[0006] In the conventional fuel injection controller, the timer for specifying the injection interval is started when the reference tooth is detected. Therefore, if the calculation for specifying the reference tooth is not completed before the pickup detects a tooth to be the reference tooth because of high engine speed or similar reason, the controller cannot transmit an injection signal, so that there is a possibility that the injection may be missed. By starting the timer every time a tooth is detected before the reference tooth is determined by calculation, an injection pulse signal can be transmitted to an injector, if it is before the timer count exceeds the injection interval even though the calculation for specifying the reference tooth is not completed before a tooth to be the reference tooth is detected. The injection timing accuracy can thereby be improved.

[0007] However, such control to extend the time limit of calculation regarding injection to until after detection of a reference tooth as described above has the following problem: When a tooth having a tooth number corresponding to one of the existing or missing teeth numbers in the missing tooth portion is determined by calculation as the reference tooth in a section following the section having the missing tooth portion, if the calculation of the injection start interval is started after the reference tooth is detected, the rotation time of the reference tooth in the storage region will have been renewed with the value after the detection. If such value in the rotation time storage region is corrected and used for the calculation of the injection start interval as mentioned before, injection may occur at a different timing from the calculated injection crank angle, which will increase exhaust emissions.

SUMMARY OF THE INVENTION

[0008] The present invention was made to solve this problem and it is an object of the invention to provide a fuel injection controller capable of injecting fuel to each cylinder based on a calculated injection amount and injection timing even though the time limit of calculation regarding the injection amount and timing is extended to until after the reference tooth is detected.

[0009] The fuel injection controller according to the present invention is a fuel injection controller that calculates an injection amount and an injection timing for each of a plurality of cylinders in a diesel engine based on crank angle. The fuel injection controller includes a pulser rotated with a crankshaft of the diesel engine and having a plurality of teeth with one portion missing teeth along an outer circumferential edge thereof, the teeth being divided into a plurality of sections corresponding to respective cylinders, the teeth included in each section being assigned numbers, and the numbers in respective sections corresponding to each other; a pickup detecting the teeth; and a control unit calculating an injection amount and an injection timing for each cylinder, and injecting fuel in each cylinder from fuel injection means provided for each cylinder based on the calculated injection amount and injection timing. The control unit includes: a duration timer measuring an intertooth interval indicating the duration between a time point when the pickup detects one tooth and a time point when the pickup detects the next tooth; a calculation unit calculating injection timing for injecting fuel in each cylinder, and specifying the injection timing by using the intertooth interval in a section of the pulser corresponding to a cylinder in which fuel is injected prior to the cylinder in which fuel is to be injected; a determination unit determining whether or not the intertooth interval to be used for specifying the injection timing is an intertooth interval of a missing tooth portion of the pulser; and a storage unit storing the intertooth interval measured by the duration timer, the stored intertooth interval being renewed with an intertooth interval of a tooth of the same number as that of a tooth of the stored intertooth interval when the intertooth interval of the tooth of the same number is input. When the intertooth interval to be used for specifying the injection timing is the intertooth interval of the missing tooth portion, the calculation unit converts the intertooth interval to be used for specifying the injection timing based on the tooth number of a tooth that is most recently detected by the pickup at a time point when the intertooth interval is used to specify the injection timing, and uses the converted intertooth interval for specifying the injection timing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a schematic configuration diagram of a diesel engine equipped with a fuel injection controller

according to one embodiment of the present invention;

FIG. 2 is a diagram for illustrating the configuration of an engine rotation sensor provided in the fuel injection controller according to the above embodiment;

FIG. 3 is a diagram for explaining the process step of calculating an injection amount when the missing tooth portion is not present in a section having a TDC or in the first and second previous sections;

FIG. 4 is a diagram for explaining the process step of calculating an injection amount when the section containing an injection start reference tooth is different from that of FIG. 3;

FIG. 5 is a diagram for explaining the process step of calculating an injection amount when the missing tooth portion is present in the section before a section having a TDC;

FIG. 6 is a diagram for explaining the process step of calculating an injection amount when the section containing an injection start reference tooth is different from that of FIG. 5;

FIG. 7 is a diagram for explaining the process step of calculating an injection amount when the missing tooth portion is present in the second section previous a section having a TDC;

FIG. 8 is a diagram for explaining the process step of calculating an injection amount when the section containing an injection start reference tooth is different from that of FIG. 7, illustrating a condition where the engine speed is high; and

FIG. 9 shows the same example as FIG. 8 where the engine speed is low.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] Embodiments of the present invention will be hereinafter described with reference to the accompanying drawings.

[0012] FIG. 1 shows the configuration of a diesel engine having a fuel injection controller 100 according to one embodiment of the present invention. The diesel engine 1 is a common rail diesel engine having eight cylinders in a V configuration. Each of the cylinders 2 (only one of them being shown in FIG. 1) includes an injector 3 inside, which is the fuel injection means. The injectors 3 each have a solenoid valve 4 that opens and closes the passage of injected fuel.

[0013] The injectors 3 are connected to a common rail 5 via high pressure fuel pipes 14. The common rail 5 stores fuel at high pressure. When the solenoid valve 4 opens, the pressure inside the common rail 5 pumps out the fuel, which travels through the fuel pipes 14 and is injected from the injector 3. A supply pump 6 supplies fuel at high pressure from a fuel tank 7 to the common rail 5, so that the pressure inside the common rail 5 is maintained at a predetermined level.

[0014] The diesel engine 1 includes an ECU 8 that controls the operation of the diesel engine 1. To the ECU 8 are electrically connected an engine rotation sensor 9 that detects the crank angle and the engine speed of the diesel engine 1, and a drive circuit 10. The solenoid valves 4 are electrically connected to the drive circuit 10. The ECU 8 constitutes the control unit in the claims.

[0015] The ECU 8 includes a calculation unit 15 for calculating an amount of fuel to be injected and the timing for starting the injection based on the running condition of the diesel engine 1, and an injection timer 16 that transmits pulse signals indicative of the timing for opening and closing the solenoid valves 4 based on the injection amount and timing determined by the calculation unit 15 to the drive circuit 10. The injection timer 16 further includes a determination unit 17 that checks the information used to transmit pulse signals, and a storage unit 18 storing the information associated with the injection in the respective cylinders 2. The calculation unit 15 and the injection timer 16 are mutually accessible.

[0016] To determine the injection timing, the calculation unit 15 first calculates an injection start crank angle. Based on the calculated injection start crank angle, the calculation unit 15 determines by calculation an injection start reference tooth of a pulser 9a (see FIG. 2) to be described later of the engine rotation sensor 9 to be used as the reference to start the injection, and an injection start interval indicating a duration between the detection of the injection start reference tooth and the actual injection. Also, based on the calculated crank angle, injection amount, etc., the calculation unit 15 calculates the duration of injection from the above injection start crank angle, as the timing for ending the injection. The calculation unit 15 then stores the determined injection start reference tooth, injection start interval, and injection duration in the storage unit 18 of the injection timer 16. The injection start reference tooth and the injection start interval specify the timing for starting injection, while the injection duration specifies the timing for ending the injection. Thus the injection timer 16 transmits pulse signals indicative of the timing for opening and closing the solenoid valves 4 based on the information stored in the storage unit 18 to the drive circuit 10.

[0017] The ECU 8 further includes a duration timer 19 that measures the duration from a detection time point of one tooth 12 (see FIG. 2) of the pulser 9a detected by a pickup 9b (see FIG. 2) to be described later of the engine rotation sensor 9. The duration timer 19 measures the duration with respect to each of the teeth 12 of the pulser 9a and can mutually access both the calculation unit 15 and the injection timer 16.

[0018] As shown in FIG. 2, the engine rotation sensor 9 includes the pulser 9a and the pickup 9b. The pulser 9a is disc-shaped, and connected at its center to the crankshaft 11 of the diesel engine 1 (see FIG. 1) so as to rotate with the crankshaft 11. Thirty-four teeth 12 are formed on the outer circumference of the pulser 9a. The entire outer circumference of the pulser 9a is divided into

36 sections and these teeth 12 are each located in the respective sections, with a non-toothed part 13 being present at a location corresponding to two teeth as indicated by a broken line. Namely, two teeth are missing.

These teeth 12 are divided at 90° into four sections A to D, and are assigned with numbers from 0 to 8 in each of the sections A to D. As section D with the non-toothed part 13 has only seven teeth, the teeth 12 in section D are assigned with numbers from 0 to 6. The zone between detection of tooth No. 6 in section D and detection of tooth No. 0 in section A will be referred to as "missing tooth zone 13a", which constitutes the missing tooth portion in the claims. The missing tooth zone 13a includes a tooth which has tooth No. 6 and missing teeth which make teeth No. 7 and No. 8 missing in section D.

[0019] The pickup 9b is a magnetic sensor arranged opposite the teeth 12 and transmits pulse signals to the ECU 8, to which it is electrically connected to, as the pulser 9a rotates and the respective teeth 12 approach. The ECU 8 determines the rotation speed of the pulser 9a, i.e., of the crankshaft 11, based on the interval between the received pulse signals. When the ECU 8 detects the non-toothed part 13, in which no pulse signals are detected, it also determines the crank angle (CA) based on the number of pulse signals detected after the detection of the non-toothed part 13. In this example, tooth No. 5 corresponds to the compression top dead center (TDC) of each cylinder.

[0020] As the pulser 9a rotates, the pickup 9b detects the teeth 12 in respective sections in the order of A-B-C-D-A, and detects the teeth 12 in each section in the order of No. 0 to No. 8. The section that has the TDC of the cylinder 2 (see FIG. 1) in which the fuel is to be injected changes as the pulser 9a rotates in the order of A-B-C-D-A.

[0021] The fuel injection controller 100 is constituted by the engine rotation sensor 9 including the pulser 9a and the pickup 9b, and the ECU 8 (also see FIG. 1).

[0022] Next, the operation of the fuel injection controller 100 according to this embodiment will be described.

[0023] Referring to both of FIG. 1 and FIG. 2, the calculation unit 15 calculates the amount of fuel to be injected to each of the eight cylinders 2 of the diesel engine 1 and the injection start crank angle, which represents the timing for starting the injection, at a timing based on the crank angle. This timing may be changed as required in accordance with the processing speed of the ECU 8.

[0024] From the calculated injection start crank angle, the calculation unit 15 determines a specific tooth as a reference tooth for starting injection (that is, an injection start reference tooth). This injection start reference tooth is the one that is to be detected by the pickup 9b immediately before the injection start crank angle. The calculation unit 15 further calculates an injection start interval, which is the time between detection of the injection start reference tooth by the pickup 9b and the start of injection, based on the injection start crank angle, the crank angle of the injection start reference tooth, and the engine

speed of the diesel engine 1, etc. Next, the calculation unit 15 calculates the injection duration from the injection amount and the fuel pressure in the common rail 5 (common rail pressure).

[0025] The calculation unit 15 then stores the calculation results, which include the calculated injection amount, injection start crank angle, injection start reference tooth, injection start interval and injection duration, in the storage unit 18 of the injection timer 16.

[0026] The crank angle of the injection start reference tooth is a crank angle at a time point when the pickup 9b has started detecting the injection start reference tooth. The engine speed used for calculating the injection start interval is the rotation speed of a tooth of the same number as the injection start reference tooth in a section before the section where the reference tooth is present, the rotation speed being the number of rotations calculated by the calculation unit 15 from the duration measured by the duration timer 19 between detection of the tooth of the same number by the pickup 9b and detection of the next tooth. The duration timer 19 is configured to reset the measuring duration each time a next tooth 12 is detected by the pickup 9b so that it measures durations between detection time points of one tooth 12 and the next tooth continually and stores the measurements in the storage unit 18.

[0027] The injection timer 16 acquires the injection start reference teeth and intervals, and injection durations from the storage unit 18 so that the solenoid valves 4 are driven at calculated injection start crank angles. After the duration is reset at the start of detection of the injection start reference tooth by the pickup 9b, the determination unit 17 of the injection timer 16 compares the duration being measured by the duration timer 19 with the injection start interval, and sends a signal to the injection timer 16 indicative of the timing when the duration measured by the duration timer 19 reaches the injection start interval, whereupon the injection timer 16 outputs a pulse signal to the drive circuit 10 instructing it to open the solenoid valve 4.

[0028] After the output of the pulse signal instructing to open the solenoid valve 4, the determination unit 17 of the injection timer 16 accumulates the durations that are measured by the duration timer 19 and reset every time a tooth 12 is detected, and sends a signal to the injection timer 16 indicative of the timing when the accumulated time reaches the injection duration, whereupon the injection timer 16 outputs a pulse signal to the drive circuit 10 instructing it to close the solenoid valve 4, instead of the pulse signal instructing to open the solenoid valve 4.

[0029] The solenoid valve 4 is thus controlled to open and close based on measuring the time from the detection of the injection start reference tooth until the end of the injection start interval, and the duration after the start of injection. The injection amount does not only mean the total amount of fuel injected to each cylinder 2. Since fuel is injected in each cylinder 2 several times as multiple

injections such as main injection, post injection, etc., the injection amount here should be understood to also mean the number of multiple injections and each amount of the injections (each injection duration). Calculating an injection timing should be understood to mean calculating an injection start crank angle for each of multiple injections performed to each cylinder 2.

[0030] The calculation unit 15 stores the injection start reference tooth, injection start interval, and injection duration of an immediately previous injection to a cylinder 2 in the storage unit 18 of the injection timer 16. Sometimes, the calculated injection start reference tooth is advanced to a tooth in a section before the section with the TDC of the cylinder where injection is to be performed, whereby the calculation time for calculating the injection amount and timing is made short and the calculation of the injection amount and timing may not be complete before the end of the injection start interval at the injection start reference tooth of the previous injection. In such a case, the calculation unit 15 refers to the timing of the previous injection stored in the storage unit 18 to prevent an injection from being missed.

[0031] Next, the calculation process at the calculation unit 15 will be described in detail.

[0032] First, control of injection in a cylinder having the TDC in section C will be illustrated. A pilot injection, wherein the actual injection follows quickly after the start of calculation of the injection amount and timing, will be described as one example. The non-toothed part 13 is not present in section C with tooth No. 5 that is the TDC, nor is it present in the two previous sections A or B.

[0033] As shown in FIG. 3 and FIG. 4, the calculation of the injection amount and timing is started at a time point when tooth No. 2 is detected by the pickup 9b (see FIG. 2) in section B, the section before section C with tooth No. 5 that is the TDC. For the pilot injection in section C, one of the teeth from No. 6 in section B to No. 6 in section C with the TDC will be determined as the injection start reference tooth.

[0034] As shown in FIG. 3 and FIG. 4, when the pickup 9b (see FIG. 2) detects tooth No. 2 in section B that is the section before section C, the calculation unit 15 (see FIG. 1) starts calculating the injection amount and injection start crank angle. The duration timer 19 (see FIG. 1) is also operating at this time, continually measuring the duration from the start of detection of every tooth.

[0035] Referring also to FIG. 1, the duration timer 19 measures the period of time from detection of one tooth and reset to the detection of a next tooth and reset, i.e., the tooth-to-tooth time interval (hereinafter "intertooth interval"), and stores this time interval with respect to each tooth in the storage unit 18. The intertooth interval between detection of tooth No. 0 and detection of tooth No. 1, for example, is referred to here as "intertooth interval of tooth No. 0", or "intertooth interval corresponding to tooth No. 0".

[0036] The storage unit 18 handles the intertooth intervals of teeth of the same number measured by the

duration timer 19 as one group irrespective of which section they are in and stores these intertooth intervals of teeth in corresponding interval storage regions set for respective numbers of teeth. Every time a new intertooth interval is sent from the duration timer 19, the storage unit 18 stores it, i.e., renews the intertooth interval stored in the interval storage region of the tooth of the same number. Every time the intertooth interval of tooth No. 0 in section A, B, C, or D is sent from the duration timer 19, for example, the storage unit 18 sets the intertooth interval that has been sent as the new intertooth interval in the interval storage region for tooth No. 0. This intertooth interval is used for the calculation of the injection start interval by the calculation unit 15.

[0037] In this example, calculation of the injection amount and the injection start crank angle and determination of the injection start reference tooth (hereinafter "first calculation") are completed within a period after the pickup 9b (see FIG. 2) detects tooth No. 2 in section B before it detects tooth No. 8 after detecting tooth No. 7. Calculation of the injection start interval and the injection duration (hereinafter "second calculation") is completed within a period after the completion of the first calculation before tooth No. 8 is detected. The length of time required for the first or second calculation varies depending on the performance or load of the calculation unit 15, and the engine speed of the diesel engine 1. At low speed, the second calculation will end before tooth No. 6 is detected by the pickup 9b, for example, while, at high speed, it will end sometime after tooth No. 6 is detected and before tooth No. 8 is detected.

[0038] FIG. 3 shows an example in which, the injection start crank angle, which is changed depending on the running condition, has been calculated as being, for example, between tooth No. 1 and tooth No. 2 in section C.

[0039] Referring also to FIG. 1, the calculation unit 15 performs the first calculation and sets tooth No. 1 of section C, which is immediately before the injection start crank angle (for initiating injection), as the injection start reference tooth.

[0040] Next, the calculation unit 15 performs the second calculation to compute the injection start interval between the detection of tooth No. 1 of section C by the pickup 9b (see FIG. 2) and the start of injection, and calculates the injection duration afterwards.

[0041] The calculation unit 15 acquires an intertooth interval stored in the interval storage region for tooth No. 1 of the storage unit 18 of the injection timer 16, which is the same tooth number as the injection start reference tooth, at the time of starting the calculation of the injection start interval, which is at the time of the start of the second calculation immediately after completion of the first calculation. The calculation unit 15 then calculates the injection start interval from the time when tooth No. 1 of section C was detected by the pickup 9b (see FIG. 2) until the injection is started based on the engine speed calculated from the acquired intertooth interval, and stores the interval in the storage unit 18. The intertooth

interval the calculation unit 15 acquires from the storage unit 18 is the one measured as the intertooth interval of tooth No. 1 in section B.

[0042] The calculation unit 15 then calculates the injection duration from the injection start crank angle (initiation of injection) based on the calculated engine speed, injection amount, and common rail pressure, etc., and stores the duration in the storage unit 18.

[0043] After completion of the first calculation, before the calculation unit 15 uses the intertooth interval that it acquired from the storage unit 18 to calculate the injection start interval, the determination unit 17 of the injection timer 16 identifies the tooth corresponding to the intertooth interval to be used for the calculation of the engine speed (calculation of the injection start interval). Namely, the determination unit 17 acquires tooth No. 1 of the injection start reference tooth and the name of section C including the injection start reference tooth from the storage unit 18 to identify tooth No. 1 of the tooth and the name of section B to be used for the calculation of the injection start interval. Judging from the fact that tooth No. 1 is not any one of existing tooth No. 6 and missing teeth No. 7 and NO. 8 in the missing tooth zone 13a (see FIG. 2), the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 1 in the storage unit 18 to be used for the calculation of the injection start interval is not the intertooth interval of the missing tooth zone 13a, and transmits this determination result to the calculation unit 15.

[0044] The calculation unit 15, based on the determination result by the determination unit 17, uses the intertooth interval stored in the interval storage region for tooth No. 1 in the storage unit 18 as is, to calculate the injection start interval as described above.

[0045] Next, when the pickup 9b (see FIG. 2) detects tooth No. 1 of section C that is the injection start reference tooth, the determination unit 17 compares the time being measured by the duration timer 19 with the injection start interval. The determination unit 17 sends a signal to the injection timer 16 indicative of the timing when the time measured by the duration timer 19 reaches the injection start interval. The injection timer 16 outputs a pulse signal to the drive circuit 10 instructing it to open the solenoid valve 4, whereby fuel is injected from the solenoid valve 4. The determination unit 17 accumulates the durations measured by the duration timer 19 after the output of the pulse signal from the injection timer 16, and sends a signal to the injection timer 16 indicative of the timing when the accumulated time reaches the injection duration. The injection timer 16 then outputs a pulse signal to the drive circuit 10 instructing it to end the injection.

[0046] Next, FIG. 4 shows a case in which the injection start crank angle is advanced so that injection is started before the pickup 9b (see FIG. 2) detects tooth No. 0 of section C. In the illustrated case the injection is started after the pickup 9b detects tooth No. 7 of section B before detecting tooth No. 8.

[0047] Referring also to FIG. 1, once the calculation

unit 15 completes the first calculation which is calculation of the injection amount and the injection start crank angle and determines the injection start reference tooth, it calculates, as the second calculation, the injection start interval between detection of the injection start reference tooth by the pickup 9b (see FIG. 2) and start of injection, as has been described above, and stores the interval in the storage unit 18 of the injection timer 16.

[0048] Next, the determination unit 17 of the injection timer 16 compares the number of the injection start reference tooth with the tooth most recently detected by the pickup 9b. If the number of the most recently detected tooth is smaller than that of the injection start reference tooth, the determination unit 17 waits until the pickup 9b detects the injection start reference tooth, and after the reference tooth is detected, sends a signal to the injection timer 16 indicative of the timing when the time measured by the duration timer 19 equals to the injection start interval. Thereupon the injection timer 16 outputs a pulse signal to the drive circuit 10 to open the solenoid valve 4.

[0049] If the number of the tooth most recently detected by the pickup 9b (see FIG. 2) is the same as that of the injection start reference tooth (both being tooth No. 7 in section B), the determination unit 17 compares the time measured by the duration timer 19 with the injection start interval and sends the comparison result to the injection timer 16. If the time measured by the duration timer 19 is shorter than the injection start interval, and when the output of the pulse signal does not exceed a limit, the injection timer 16 determines that injection is possible and outputs a pulse signal to the drive circuit 10 to open the solenoid valve 4. Otherwise, the injection timer 16 determines that injection is not possible, as the calculation of the injection amount and timing will not be completed before the injection start crank angle is reached, and outputs a pulse signal to the drive circuit 10 for opening the solenoid valve 4 in an amount and at a timing determined previously for the same cylinder, so as to prevent injection being missed. Similarly, if the injection timing used previously for the same cylinder has come before the completion of calculation of the injection amount and timing, the injection timer 16 outputs a pulse signal to the drive circuit 10 for opening the solenoid valve 4 in an amount and at a timing determined previously for the same cylinder, so as to prevent the injection being missed.

[0050] Next, the control of injection in a cylinder that has the TDC in section A, which is the next one of section D including the non-toothed part 13, will be illustrated.

[0051] As shown in FIG. 5 and FIG. 6, since there are no teeth in the non-toothed part 13, when measuring the intertooth interval in section D, the duration timer 19 (see FIG. 1) measures the duration between detection time points of tooth No. 6 in section D and tooth No. 0 in section A, and stores it as the intertooth interval of tooth No. 6 of section D in the storage unit 18 (see FIG. 1).

[0052] FIG. 5 shows an example in which injection is started after the pickup 9b (see FIG. 2) detects tooth No.

6 of section A. If the injection start reference tooth is any of the teeth No. 0 to No. 5 of section A, then the calculation is performed in the same procedure as that for calculating the injection amount for the cylinder having the TDC in section C as shown in FIG. 3 and described above, and the fuel is injected in a manner similar to that described above.

[0053] Referring both to FIG. 5 and FIG. 1, after the first calculation, the calculation unit 15 calculates the engine speed of the diesel engine 1 to be used for the calculation of the injection start interval after the detection of the injection start reference tooth by the pickup 9b (see FIG. 2), by using the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 at the start of the second calculation, i.e., at the start of calculation of the injection start interval.

[0054] At the start of calculation of the injection start interval, tooth No. 0 in section A has not been detected yet by the pickup 9b and the duration timer 19 has not finished measuring the intertooth interval of tooth No. 6 of section D yet. Therefore, the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 is the one measured in section C before section D.

[0055] Before the calculation unit 15 uses the intertooth interval acquired from the storage unit 18 to calculate the injection start interval, the determination unit 17 of the injection timer 16 acquires the injection start reference tooth No. 6 and the name of section A that includes the injection start reference tooth to identify tooth No. 6 used for the injection start reference tooth and the name of section D to be used for the calculation of the injection start interval. Since tooth No. 6 of section D is in the missing tooth zone 13a, the determination unit 17 further acquires tooth No. 6 of the tooth most recently detected by the pickup 9b (see FIG. 2) and the name of section D that this detected tooth belongs to, at the time point when the calculation unit 15 acquires the intertooth interval from the storage unit 18. Based on this, the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 to be used for the calculation of the injection start interval has not been renewed yet in section D but is the one measured in section C and that therefore it is not the intertooth interval of the missing tooth zone 13a, and transmits this determination result to the calculation unit 15. The calculation unit 15, based on the determination result by the determination unit 17, uses the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 as it is, to calculate the injection start interval.

[0056] Using the thus calculated injection start interval and the injection start reference tooth and the injection duration, the injection timer 16 outputs pulse signals to the drive circuit 10 to control the opening and closing of the solenoid valves 4.

[0057] Next, FIG. 6 shows a case in which injection is started before the pickup 9b (see FIG. 2) detects tooth No. 0 of section A. In the illustrated case, the injection

start crank angle is determined to be in the non-toothed part 13 of section D. Further, FIG. 6 illustrates a case in which the injection start crank angle is advanced similarly to FIG. 4.

[0058] Referring also to FIG. 1, the calculation unit 15 calculates the injection start crank angle, which is the timing for starting injection. Here, the calculated injection start crank angle is positioned within the non-toothed part 13. Therefore, the calculation unit 15 sets tooth No. 6 of section D as the injection start reference tooth, and calculates, as the injection start interval, the duration from the detection of tooth No. 6 by the pickup 9b (see FIG. 2) until the calculated injection start crank angle for starting injection is reached.

[0059] Before the calculation unit 15 uses the intertooth interval acquired from the storage unit 18 to calculate the injection start interval, the determination unit 17 of the injection timer 16 acquires tooth No. 6 of the injection start reference tooth and the name of section D that includes the injection start reference tooth to identify tooth No. 6 of the tooth and the name of section C to be used for the calculation of the injection start interval. The determination unit 17 determines that the injection start reference tooth corresponds to one of the existing or missing teeth in the missing tooth zone 13a of section D. The determination unit 17 further acquires the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2) and the name of the section that this detected tooth belongs to, at the time point when the calculation unit 15 acquires the intertooth interval from the storage unit 18. Here, the determination unit 17 acquires the section name D and the number six as the number of the most recently detected tooth. Based on this, the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 to be used for the calculation of the injection start interval has not been renewed yet in section D but is the one measured in section C and that therefore it is not the intertooth interval of the missing tooth zone 13a, and transmits this determination result to the calculation unit 15.

[0060] The calculation unit 15, based on the determination result by the determination unit 17, uses the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 as it is, which is the intertooth interval of tooth No. 6 in section C, to calculate the interval from after the pickup 9b detects tooth No. 6 until the injection is started, and stores the interval in the storage unit 18.

[0061] The determination unit 17 compares the time measured by the duration timer 19 after the detection of tooth No. 6 in section D with the injection start interval and sends the comparison result to the injection timer 16. If the time measured by the duration timer 19 is shorter than the injection start interval, and if the output of the pulse signal does not exceed a limit, the injection timer 16 determines that injection is possible and outputs a pulse signal to the drive circuit 10 to open the solenoid

valve 4. Thereby, the period until the completion of calculation of the injection amount is extended to immediately before the injection. Otherwise, the injection timer 16 operates in a manner similar to that in the case shown in FIG. 4.

[0062] Next, the control of injection in a cylinder that has the TDC in section B, which is the next section after section A, will be illustrated. Namely, section B is the second section after section D which has the non-toothed part 13.

[0063] FIG. 7 shows an example in which injection is started after the pickup 9b (see FIG. 2) detected tooth No. 0 of section B. Here, calculation is performed in the same procedure as done to calculate the injection amount for section C as shown in FIG. 3 and described above, and the fuel is injected in a manner similar to that described above.

[0064] Next, FIG. 8 shows a case in which injection is started before the pickup 9b (see FIG. 2) detects tooth No. 0 of section B. In the illustrated case, tooth No. 7 in section A is set as the injection start reference tooth. FIG. 8 shows an example in which the engine speed of the diesel engine 1 (see FIG. 1) is high, where the second calculation is completed at a time point after the pickup 9b detects tooth No. 7 of section A and before it detects tooth No. 8.

[0065] Referring both FIG. 8 and FIG. 1, the calculation unit 15 calculates the engine speed of the diesel engine 1 after the detection of the injection start reference tooth by the pickup 9b (see FIG. 2) to be used for the calculation of the injection start interval, by using the intertooth interval stored in the interval storage region for tooth No. 6 in the storage unit 18 at the start of the calculation of the injection start interval, which is at the start of the second calculation. In section D having the non-toothed part 13, missing tooth No. 7 and tooth No. 8 are not detected by the pickup 9b. Therefore, the intertooth intervals stored in the interval storage regions for tooth No. 7 and tooth No. 8 of section A are equal to those measured in section C which is the second previous section. For the calculation of the injection start interval, the rotation time (intertooth interval) of the section immediately before the section in which injection is performed should be used for higher accuracy. Therefore, when tooth No. 7 or tooth No. 8 in section A is determined to be the injection start reference tooth, the intertooth interval of tooth No. 6 of section D is used. Thus, when any of the teeth from No. 6 to No. 8 of section A is determined to be the injection start reference tooth, the intertooth interval of tooth No. 6 is used. At the time point when tooth No. 0 of section A is detected by the pickup 9b, the most recently renewed and stored value in the interval storage region for tooth No. 6 is the time from the detection of tooth No. 6 in section D until the detection of tooth No. 0 of section A.

[0066] Before the calculation unit 15 uses the intertooth interval acquired from the storage unit 18 at the start of calculating the injection start interval, the determination unit 17 identifies the tooth corresponding to the intertooth

interval to be used for the calculation of engine speed. Namely, the determination unit 17 acquires tooth No. 7 of the injection start reference tooth and the name of section A including the injection start reference tooth, which are stored in the storage unit 18, to identify tooth No. 7 used for the injection start reference tooth and the name of section D to be used for the calculation of the injection start interval. Based on this, the determination unit 17 determines that the intertooth interval to be used for the calculation of the injection start interval is the intertooth interval of the missing tooth zone 13a in section D. The determination unit 17 further acquires the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2) at the time point when the calculation unit 15 acquires the intertooth interval from the storage unit 18, and the name of section A where this detected tooth belongs.

[0067] The determination unit 17 checks whether or not the intertooth interval of tooth No. 6 in section D stored in the storage unit 18 as the intertooth interval of teeth No. 6 to No. 8 before the calculation of the injection start interval has been renewed with a new value at the time of calculating the injection start interval. Here, the determination unit 17 compares tooth No. 7 of the injection start reference tooth that is the same as that of the tooth to be used for the calculation of the injection start interval with the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2).

[0068] If the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2) is smaller than tooth No. 7 of the injection start reference tooth, i.e., the above number is tooth No. 6 or less, tooth No. 6 reflecting the intertooth interval of the missing tooth zone 13a, it means that the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 is still the intertooth interval measured in section D and has not been renewed with that to be measured in section A yet. In this case, the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 has not been renewed yet and is still the intertooth interval of tooth No. 6 in section D and that it is the intertooth interval of the missing tooth zone 13a.

[0069] The intertooth interval of tooth No. 6 in section D here equals the duration between detection of tooth No. 6 and detection of tooth No. 0 in section A, i.e., it is the intertooth interval equal to one existing tooth and two missing teeth.

[0070] Therefore, based on the determination result by the determination unit 17, after acquiring the intertooth interval of tooth No. 6 of section D from the storage unit 18 as the intertooth interval of tooth No. 7, the calculation unit 15 divides the acquired intertooth interval by three, and uses this value for calculating the engine speed, and for calculating the injection start interval.

[0071] Here, the above tooth No. 6 constitutes the first tooth number and the above tooth No. 7 constitutes the second tooth number in the claims.

[0072] On the other hand, if the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2) equals tooth No. 7 of the injection start reference tooth (see FIG. 8), i.e., the above number is larger than tooth No. 6 which reflects the intertooth interval of the missing tooth zone 13a, it means that the pickup 9b has already detected tooth No. 7 in section A, and that the duration timer 19 has completed measurement of the intertooth interval of tooth No. 6 in section A. Therefore, the intertooth interval measured in section D and stored in the interval storage region for tooth No. 6 of the storage unit 18 has already been renewed with the one measured in section A.

[0073] Accordingly, the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 has been renewed with the intertooth interval of tooth No. 6 in section A and that it is not the intertooth interval of the missing tooth zone 13a.

[0074] Therefore, based on the determination result by the determination unit 17, after acquiring the intertooth interval of tooth No. 6 in section A from the storage unit 18 as the intertooth interval of tooth No. 7, the calculation unit 15 does not divide the acquired intertooth interval by three but uses this value as it is for calculating the engine speed, and for calculating the injection start interval.

[0075] Using the thus calculated injection start interval and the injection start reference tooth and the injection duration, the injection timer 16 outputs pulse signals to the drive circuit 10 similarly to the example shown in FIG. 4 to control the opening and closing of the solenoid valves 4.

[0076] If tooth No. 8 in section A is determined as the injection start reference tooth, the calculation and control are performed similarly to those in conjunction with tooth No. 7 described above. Namely, if the tooth number of the tooth most recently detected by the pickup 9b (see FIG. 2) is tooth No. 6 or less, tooth No. 6 reflecting the intertooth interval of the missing tooth zone 13a, the intertooth interval of tooth No. 6 in section D is used by being divided by three. If the tooth number of the tooth most recently detected by the pickup 9b is larger than tooth No. 6, the intertooth interval of tooth No. 6 in section A is used as is.

[0077] If tooth No. 6 in section A is determined as the injection start reference tooth, the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 at the start of calculation of the injection start interval has not been renewed yet and is still the intertooth interval of tooth No. 6 of section D. Therefore, the determination unit 17 determines that the intertooth interval of tooth No. 6 to be used for the calculation is the intertooth interval of the missing tooth zone 13a. The calculation unit 15 acquires the intertooth interval of tooth No. 6 of section D from the storage unit 18 as the intertooth interval of tooth No. 6 based on the determination result by the determination unit 17, and calculates the injection start interval. Here, the calculation unit uses a

value obtained by dividing the acquired intertooth interval of tooth No. 6 of section D by three.

[0078] As described above, at the start of calculation of the injection start interval, the determination unit 17 compares the tooth number of the injection start reference tooth that is the same as that of the tooth to be used for calculation of the injection start interval with the tooth number of the tooth most recently detected by the pickup 9b at the time point when the calculation unit 15 acquires the intertooth interval from the storage unit 18, and determines, based on the comparison, whether or not the intertooth interval measured in section D including the non-toothed part 13 and stored in the interval storage region for tooth No. 6 of the storage unit 18 has been renewed with the one measured in section A. In this way, the calculation unit 15 ensures proper use of the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 based on the determination results of the determination unit 17, whereby the injection start interval is calculated with higher accuracy. With such a calculation method, the calculation unit 15 can calculate the injection start interval accurately even during high-speed rotation of the diesel engine 1.

[0079] FIG. 9 shows a case in which injection is started before the pickup 9b (see FIG. 2) detects tooth No. 0 of section B, similarly to FIG. 8. In the illustrated case, tooth No. 7 in section A is set as the injection start reference tooth. FIG. 9 shows, however, an example in which the engine speed of the diesel engine 1 (see FIG. 1) is low, where the second calculation is completed at a time point after the pickup 9b detects tooth No. 5 of section A until it detects tooth No. 6.

[0080] Referring also to FIG. 1, the calculation unit 15 calculates the engine speed of the diesel engine 1 to be used for the calculation of the injection start interval, by using the intertooth interval stored in the interval storage region for tooth No. 7 of the storage unit 18 at the start of calculation of the injection start interval, similarly to the case of FIG. 8.

[0081] The intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 at the start of calculation of the injection start interval is the intertooth interval of tooth No. 6 in section D, and the intertooth intervals stored in the interval storage regions for tooth No. 7 and tooth No. 8 are respectively the intertooth intervals of tooth No. 7 and tooth No. 8 in section C.

[0082] Before the calculation unit 15 uses the intertooth interval acquired from the storage unit 18 at the start of calculating the injection start interval, the determination unit 17 identifies the tooth corresponding to the intertooth interval to be used for the calculation of engine speed. Namely, similarly to FIG. 8, the determination unit 17 determines that the intertooth interval to be used for the calculation of the injection start interval is the intertooth interval of the missing tooth zone 13a in section D. The determination unit 17 further acquires tooth No. 5 of the tooth most recently detected by the pickup 9b (see FIG. 2) at the time point when the calculation unit 15 acquires

the intertooth interval from the storage unit 18, and the name of section A that this detected tooth belongs to.

[0083] Since the number of tooth No. 5 of the tooth number most recently detected by the pickup 9b (see FIG. 2) is smaller than the number of tooth No. 7 of the injection start reference tooth, the determination unit 17 determines that the intertooth interval stored in the interval storage region for tooth No. 6 of the storage unit 18 is still the intertooth interval of tooth No. 6 in section D and that it is the intertooth interval of the missing tooth zone 13a.

[0084] Therefore, based on the determination result by the determination unit 17, after acquiring the intertooth interval of tooth No. 6 of section D from the storage unit 18 as the intertooth interval of tooth No. 7, the calculation unit 15 divides the acquired intertooth interval by three, and uses this value for calculating the engine speed, and for calculating the injection start interval.

[0085] In this way, in the example of FIG. 9 where the engine speed of the diesel engine 1 (see FIG. 1) is low, since the second calculation is completed before the intertooth interval measured in section D and stored in the interval storage region for tooth No. 6 of the storage unit 18 is renewed with the one measured in section A, the calculation unit 15 divides the intertooth interval acquired from the storage unit 18 by three and uses this value for calculating the injection start interval.

[0086] As described above, the fuel injection controller 100 according to the embodiment of the present invention is a fuel injection controller that calculates an injection amount and injection timing for each of a plurality of cylinders 2 in a diesel engine 1 based on crank angle. The fuel injection controller 100 includes a pulser 9a rotated with a crankshaft 11 of the diesel engine 1. The pulser 9a includes a plurality of teeth 12 along an outer circumferential edge thereof, with a missing tooth zone 13a where no teeth are formed. The teeth 12 are divided into a plurality of sections corresponding to respective cylinders 2, and the teeth included in each section of the pulser 9a are assigned with numbers, the numbers in respective sections A to D of the pulser 9a corresponding to each other. The fuel injection controller 100 includes a pickup 9b that detects the teeth 12, and an ECU 8 that calculates an injection amount and injection timing for each cylinder 2, and injects fuel in each cylinder 2 from an injector 3 provided for each cylinder 2 based on the calculated injection amount and injection timing. The ECU 8 includes a duration timer 19 that measures an intertooth interval indicating a duration between a time point when the pickup 9b detects a tooth 12 and a time point when the pickup 9b detects a next tooth 12. The ECU 8 further includes a calculation unit 15 that calculates an injection timing for injecting fuel in each cylinder 2, and specifies the injection timing by using the intertooth interval in a section A to D of the pulser 9a corresponding to a cylinder 2 in which fuel is injected prior to the cylinder 2 in which fuel is to be injected. The ECU 8 includes a determination unit 17 that determines whether or not the intertooth in-

terval to be used for specifying the injection timing corresponds to an intertooth interval of a missing tooth zone 13a of the pulser 9a. The ECU 8 further includes a storage unit 18, which stores the intertooth interval measured by the duration timer 19, and renews the stored intertooth interval with a new intertooth interval of a tooth of the same number as that of a tooth of the stored intertooth interval when the new intertooth interval is input. When the intertooth interval to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth zone 13a, the calculation unit 15 converts the intertooth interval to be used for specifying the injection timing based on a tooth number of a tooth that is most recently detected by the pickup 9b at a time point when the intertooth interval is used to specify the injection timing, and uses the converted intertooth interval for specifying the injection timing.

[0087] In the above configuration, the calculation unit 15 calculates the engine speed of the diesel engine 1 using the intertooth interval that is determined every time a tooth 12 is detected by the pickup 9b to specify the injection timing. When the intertooth interval to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth zone 13a, the calculation unit 15 changes the way the intertooth interval is used for specifying the injection timing based on a tooth number of the tooth that is most recently detected by the pickup 9b at a time point when the intertooth interval is used to specify the injection timing. The storing unit 18 constantly renews the intertooth intervals corresponding to the respective teeth numbers to reflect the most recent running condition. The calculation unit 15 accordingly changes the way the intertooth interval is used for specifying the injection timing based on whether or not the intertooth interval stored in the storage unit 18 to be used for specifying the injection timing is that of the missing tooth zone 13a, or whether or not the intertooth interval of the missing tooth zone 13a has been renewed because of the pickup 9b having detected a tooth. Thus the fuel injection controller 100 is capable of injecting fuel to the respective cylinders 2 based on the injection amount and injection timing calculated such as to reflect the most recent running condition and with reduced influence by the non-toothed part 13.

[0088] In the fuel injection controller 100, when converting the intertooth interval to be used for specifying the injection timing, the calculation unit 15 divides the intertooth interval of the missing tooth zone 13a by the number of missing teeth in the missing tooth zone 13a. The calculation unit 15 thus converts the intertooth interval of the missing tooth zone 13a into an intertooth interval of one tooth and uses it.

[0089] In the fuel injection controller 100, when the intertooth interval stored in the storage unit 18 to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth zone 13a, the determination unit 17 compares a first tooth number that is a tooth number assigned to a tooth corresponding to the

intertooth interval to be used for the injection timing with a second tooth number that is a tooth number of the tooth that is most recently detected by the pickup 9b, at a time when the calculation unit 15 specifies the injection timing.

5 If the second tooth number is the same as the first tooth number or is a tooth number assigned to a tooth to be detected prior to the tooth of the first tooth number, then the determination unit 17 determines that the intertooth interval to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth zone 13a, and if the second tooth number is a tooth number assigned to a tooth to be detected after the tooth of the first tooth number, then the determination unit 17 determines that the intertooth interval to be used for specifying the injection timing does not correspond to an intertooth interval of the missing tooth zone 13a. When the determination unit 17 determines that the intertooth interval stored in the storage unit 18 to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth zone 13a, the calculation unit 15 specifies the injection timing by using the intertooth interval of the missing tooth zone 13a, while, when the determination unit 17 determines that the intertooth interval stored in the storage unit 18 to be used for specifying the injection timing does not correspond to the intertooth interval of the missing tooth zone 13a, the calculation unit 15 specifies the injection timing by using the intertooth interval of the tooth of the first tooth number renewed from the intertooth interval of the missing tooth zone 13a and stored in the storage unit 18.

[0090] In the above configuration, the determination unit 17 determines whether or not the intertooth interval of the tooth (of the first tooth number), which corresponds to the intertooth interval to be used for specifying the injection timing and which corresponds to the intertooth interval of the missing tooth zone 13a, has been renewed because of the pickup 9b having detected the tooth of the first tooth number of a new cylinder 2. If the determination unit 17 determines that the intertooth interval has not been renewed, the calculation unit 15 converts the intertooth interval of the missing tooth zone 13a before using it for specifying the interjection timing. On the other hand, if the determination unit 17 determines that the intertooth interval has been renewed, the calculation unit 15 uses the renewed intertooth interval of the tooth of the first tooth number as it is. Thus, the calculation unit 15 does not convert the renewed intertooth interval as it does when it is the intertooth interval of the missing tooth zone 13a, so that the injection timing can be specified more accurately. Namely, the influence of the missing tooth zone 13a on the specification of the injection timing is reduced.

[0091] In the fuel injection controller 100, the calculation unit 15 determines an injection start reference tooth by calculation based on a calculated injection timing, and sets a tooth of the same tooth number as that of the injection start reference tooth, as the tooth corresponding to the intertooth interval to be used for specifying the

injection timing. Thereby, the calculation unit 15 specifies the injection timing by using the intertooth interval of the tooth corresponding to the injection start reference tooth, i.e., specifies the injection timing by using the intertooth interval of the tooth when it is located at the same position as the injection start reference tooth in cylinder 2, so that the fuel injection controller 100 can perform fuel injection matching the running condition.

[0092] In this embodiment, after the intertooth interval of tooth No. 6 in section D including the non-toothed part 13 is measured, the intertooth interval of tooth No. 6 of section D is used for all the intertooth intervals of existing tooth No. 6 and missing teeth No. 7 and No. 8, but the invention is not limited to this. The intertooth interval of tooth No. 6 of section D is not used for the intertooth intervals of missing teeth No. 7 and No. 8, and the intertooth intervals of the previous section C may be used as they are.

[0093] While the duration timer 19 measures the intertooth intervals of all the teeth continuously in this embodiment, the invention is not limited to this. The duration timer 19 may make measurements intermittently, by limiting teeth whose intertooth intervals are to be measured in the next section (cylinder), based on the tooth number of the injection start reference tooth of the previous section (cylinder), the running condition, etc.

[0094] While the injection start reference tooth is selected from tooth No. 6 of the section before the section having the TDC to tooth No. 6 of the section having the TDC in this embodiment, the invention is not limited to this, and this range may be changed as required.

[0095] While the first calculation is started at a time point when the pickup 9b detects tooth No. 2 of the section before the section having the TDC in this embodiment, the invention is not limited to this, and this timing may be changed as required.

[0096] While the diesel engine 1 is an eight-cylinder diesel engine in a V configuration in this embodiment, the invention is not limited to this. As long as it has a plurality of cylinders, the diesel engine may be of any type such as an in-line engine or a flat engine.

[0097] While this embodiment has been described in connection with pilot injection as an example, the invention is applicable not only to pilot injection but also to other fuel injections into cylinders which are first carried out during one combustion cycle.

[0098] In a fuel injection controller 100, a duration timer 19 measures an intertooth interval from when a pickup detects a tooth of a pulser to when it detects a next tooth. A calculation unit 15 specifies an injection timing for each cylinder by using the intertooth interval stored in a storage unit 18. The storage unit 18 renews the stored intertooth interval with a newly input intertooth interval of a tooth of the same number as a tooth of the stored intertooth interval. When a determination unit 17 determines that the intertooth interval to be used for specifying the injection timing corresponds to an intertooth interval of a missing tooth zone 13a, the calculation unit 15 converts and uses

the intertooth interval to be used based on the number of the tooth most recently detected by the pickup when the intertooth interval is used.

Claims

1. A fuel injection controller (100) that calculates an injection amount and an injection timing for each of a plurality of cylinders (2) in a diesel engine (1) based on a crank angle, the fuel injection controller comprising:

a pulser (9a) rotated with a crankshaft (11) of the diesel engine (1) and having a plurality of teeth (12) with one portion missing teeth along an outer circumferential edge thereof, the teeth being divided into a plurality of sections (A, B, C, D) corresponding to respective cylinders (2), the teeth included in each section being assigned numbers, and the numbers in respective sections corresponding to each other;
a pickup (9b) detecting the teeth (12); and
a control unit (8) calculating an injection amount and an injection timing for each cylinder (2), and injecting fuel in each cylinder from fuel injection means (3) provided for each cylinder based on the calculated injection amount and injection timing, **characterized in that** the control unit (8) includes:

a duration timer (19) measuring an intertooth interval indicating a duration between a time point when the pickup (9b) detects one tooth (12) and a time point when the pickup detects a next tooth (12);
a calculation unit (15) calculating an injection timing for injecting fuel in each cylinder (2), and specifying the injection timing by using the intertooth interval in a section (A, B, C, D) of the pulser (9a) corresponding to a cylinder in which fuel is injected prior to the cylinder in which fuel is to be injected;
a determination unit (17) determining whether or not the intertooth interval to be used for specifying the injection timing corresponds to an intertooth interval of a missing tooth portion (13a) of the pulser (9a); and
a storage unit (18) storing the intertooth interval measured by the duration timer (19), the storage unit renewing the stored intertooth interval with a new intertooth interval of a tooth of the same number as that of a tooth of the stored intertooth interval when the new intertooth interval is input, and
when the intertooth interval to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth

- portion (13a), the calculation unit (15) converts the intertooth interval to be used for specifying the injection timing based on the tooth number of a tooth that is most recently detected by the pickup (9b) at a time point when the intertooth interval is used to specify the injection timing, and uses the converted intertooth interval for specifying the injection timing.
2. The fuel injection controller (100) according to claim 1, **characterized in that** when the intertooth interval stored in the storage unit (18) to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth portion (13a), the determination unit (17) compares a first tooth number that is the tooth number of a tooth corresponding to the intertooth interval to be used for the injection timing with a second tooth number that is the tooth number of the tooth that is most recently detected by the pickup (9b), at a time when the calculation unit (15) specifies the injection timing, and if the second tooth number is the same as the first tooth number or is a tooth number assigned to a tooth to be detected prior to the tooth of the first tooth number, then the determination unit (17) determines that the intertooth interval to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth portion (13a), and if the second tooth number is the tooth number assigned to a tooth to be detected after the tooth of the first tooth number, then the determination unit (17) determines that the intertooth interval to be used for specifying the injection timing does not correspond to the intertooth interval of the missing tooth portion (13a).
3. The fuel injection controller according to claim 2, **characterized in that** the first tooth number is the tooth number assigned to a tooth which is first detected in the missing tooth portion (13a) by the pickup (9b).
4. The fuel injection controller according to claim 2 or 3, **characterized in that** when the determination unit (17) determines that the intertooth interval stored in the storage unit (18) to be used for specifying the injection timing corresponds to the intertooth interval of the missing tooth portion (13a), the calculation unit (15) specifies the injection timing by using the intertooth interval of the missing tooth portion (13a), and when the determination unit (17) determines that the intertooth interval stored in the storage unit (18) to be used for specifying the injection timing does not correspond to the intertooth interval of the missing tooth portion (13a), the calculation unit (15) specifies the injection timing by using the intertooth interval of the tooth of the first tooth number which is renewed from the intertooth interval of the missing tooth portion (13a) and is stored in the storage unit.
5. The fuel injection controller according to any one of claims 2 to 4, **characterized in that** the calculation unit (15) determines an injection start reference tooth based on the calculated injection timing, and sets a tooth of the same tooth number as that of the injection start reference tooth, as the tooth corresponding to the intertooth interval to be used for specifying the injection timing.
6. The fuel injection controller according to any one of claims 1 to 5, **characterized in that** when converting the intertooth interval to be used for specifying the injection timing, the calculation unit (15) divides the intertooth interval of the missing tooth portion (13a) by the number of missing teeth in the missing tooth portion.

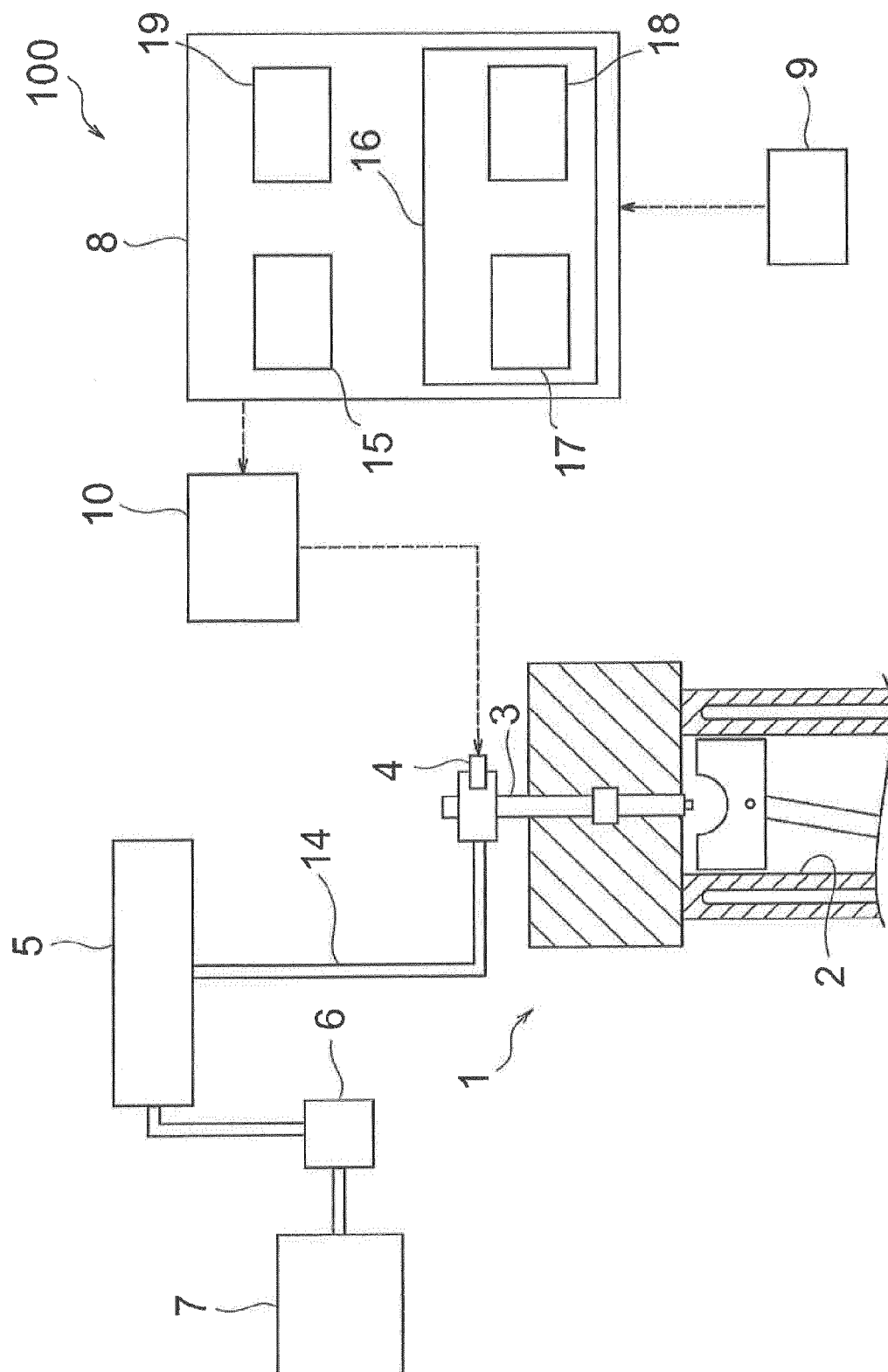


Figure 1

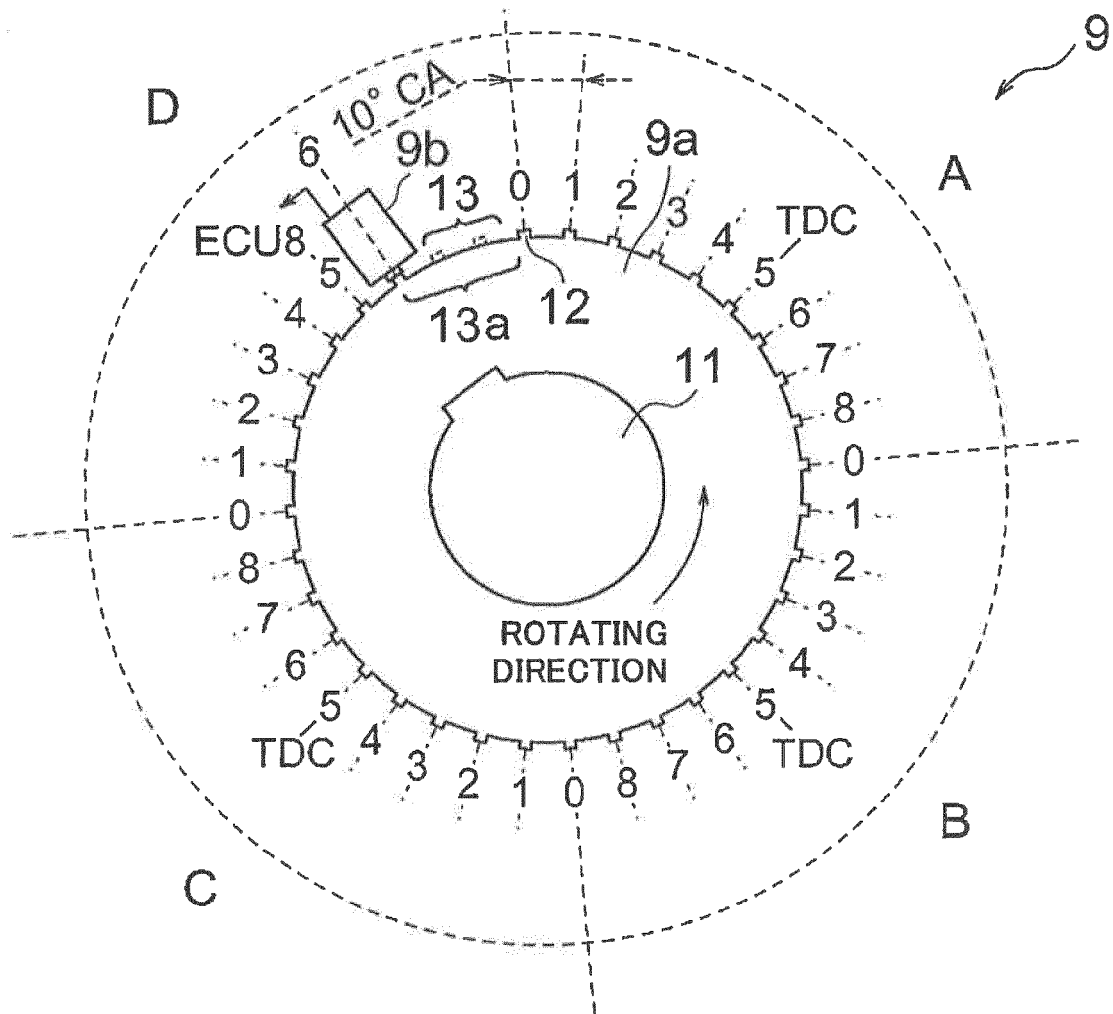


FIG.2

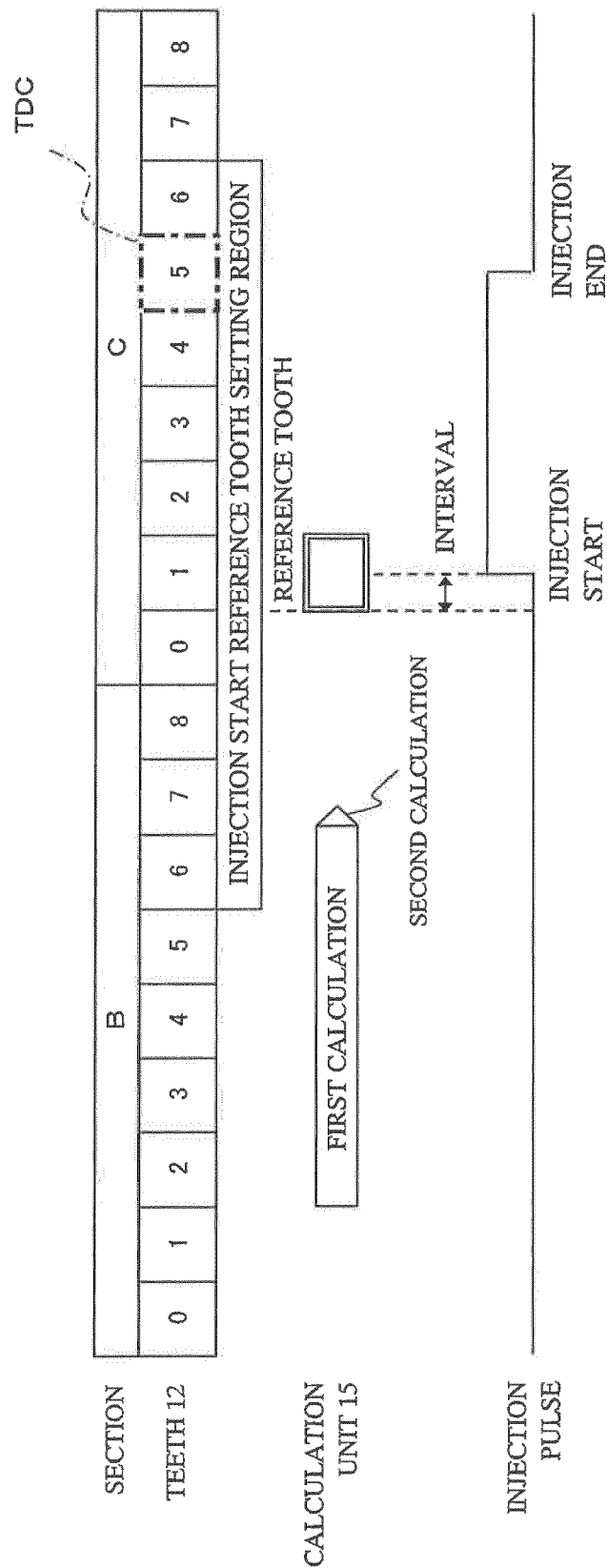


FIG.3

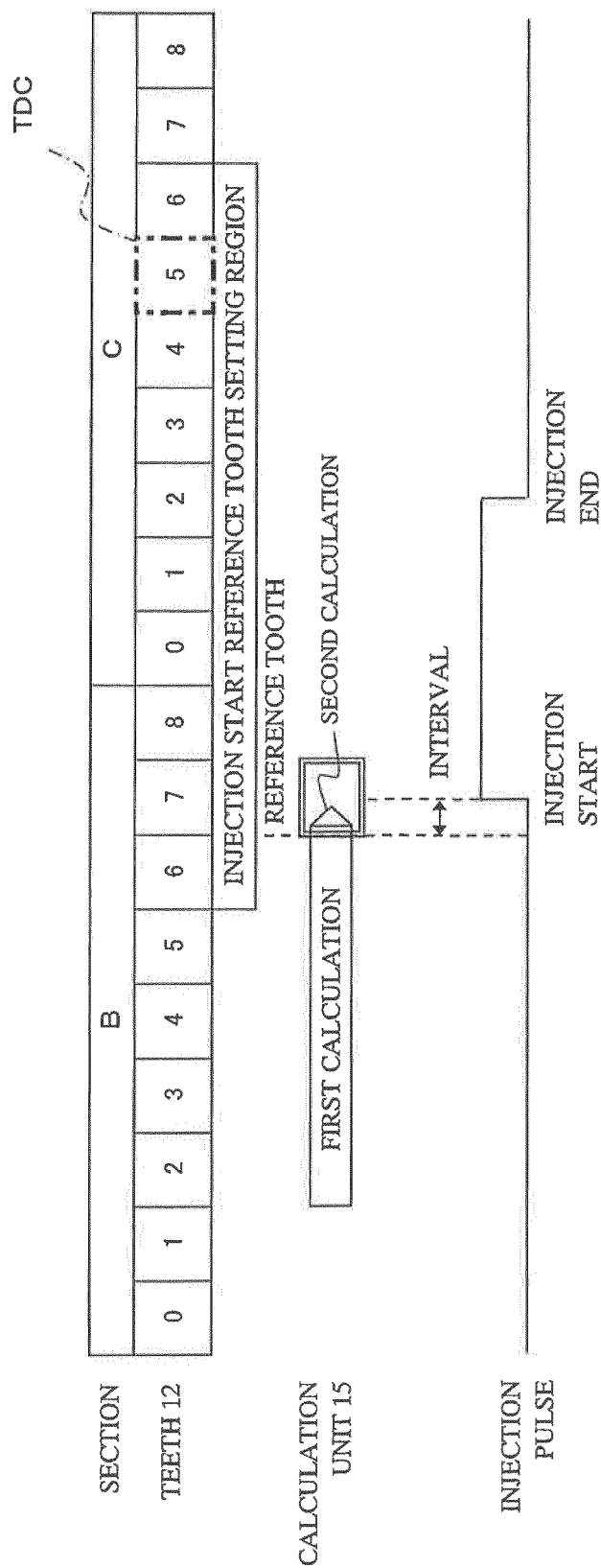


FIG.4

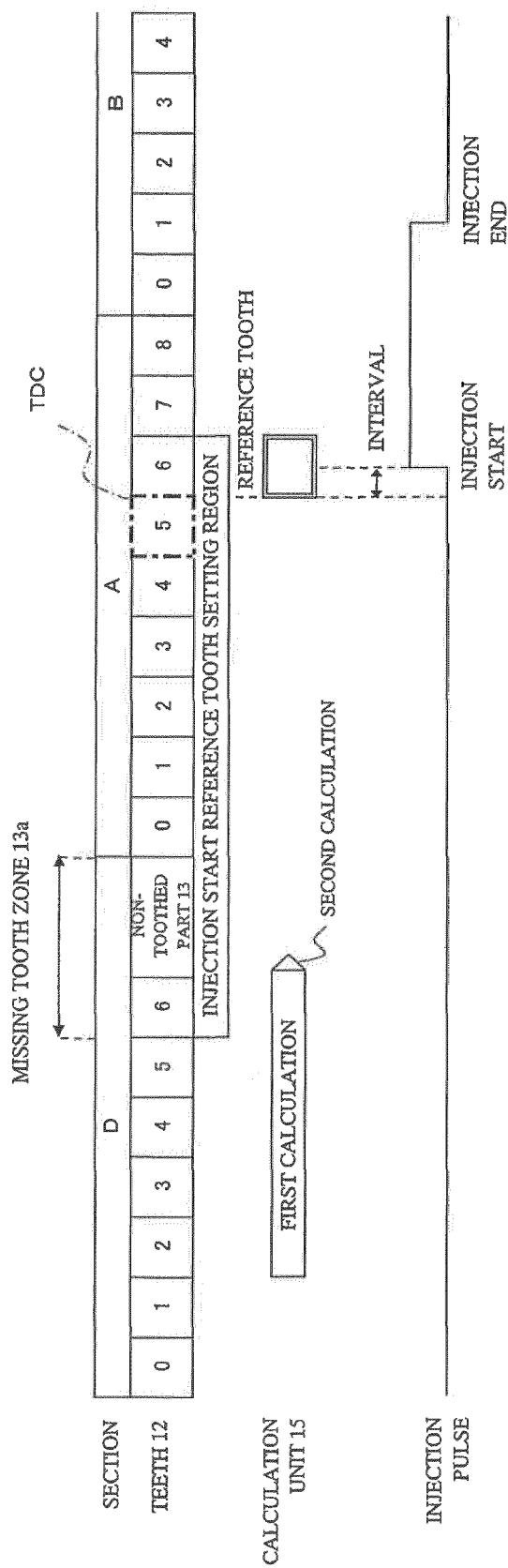


Fig. 5

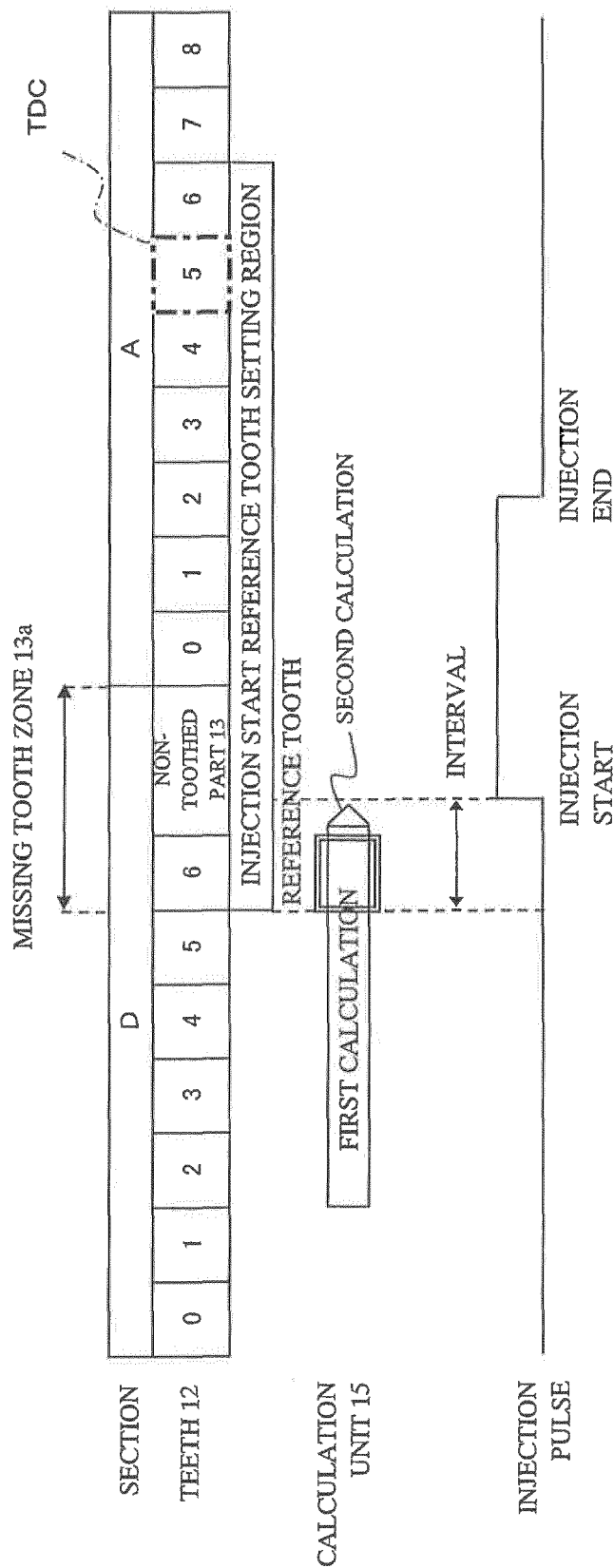


FIG.6

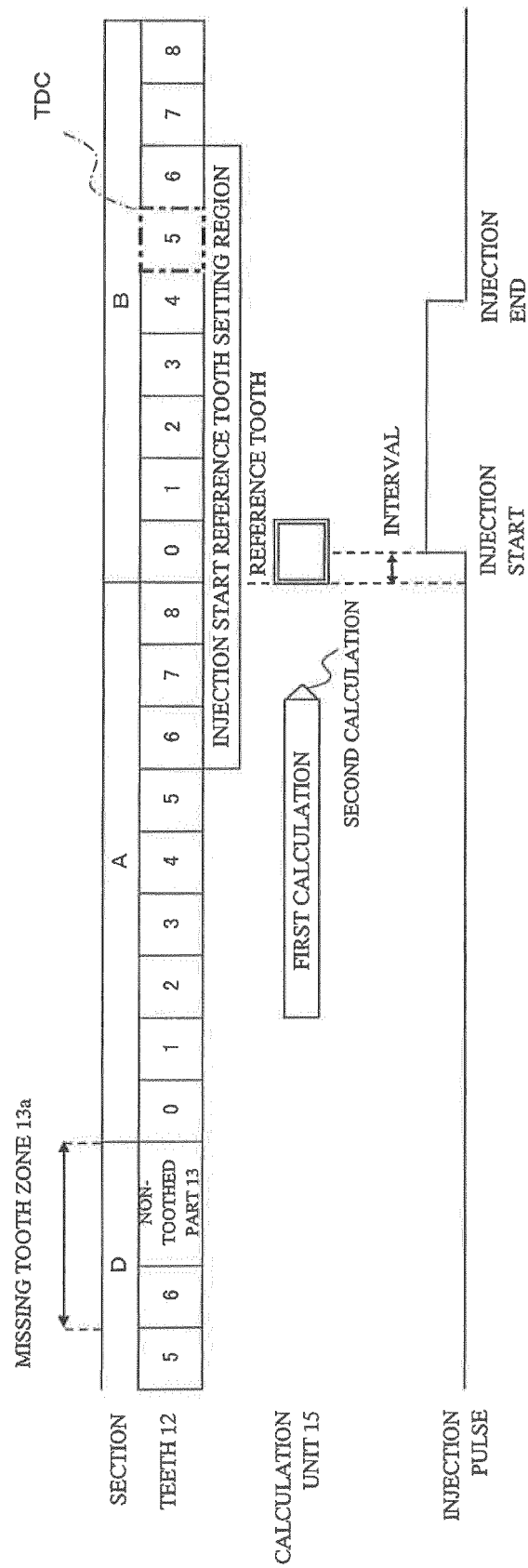


FIG.7

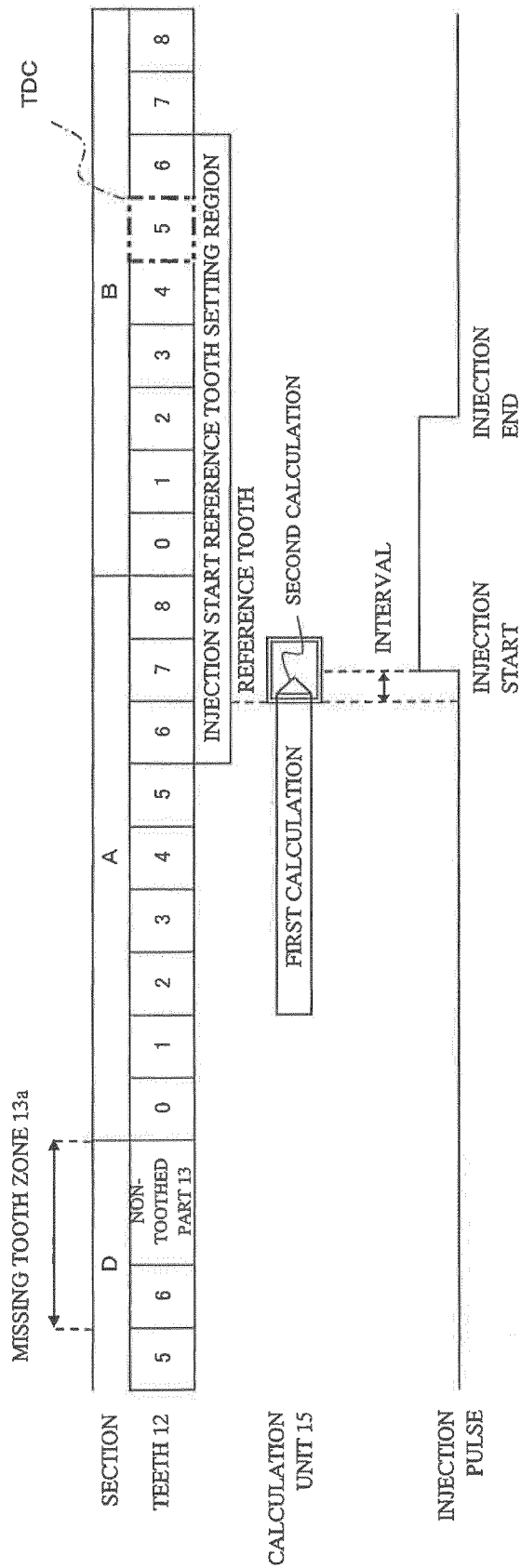


FIG.8

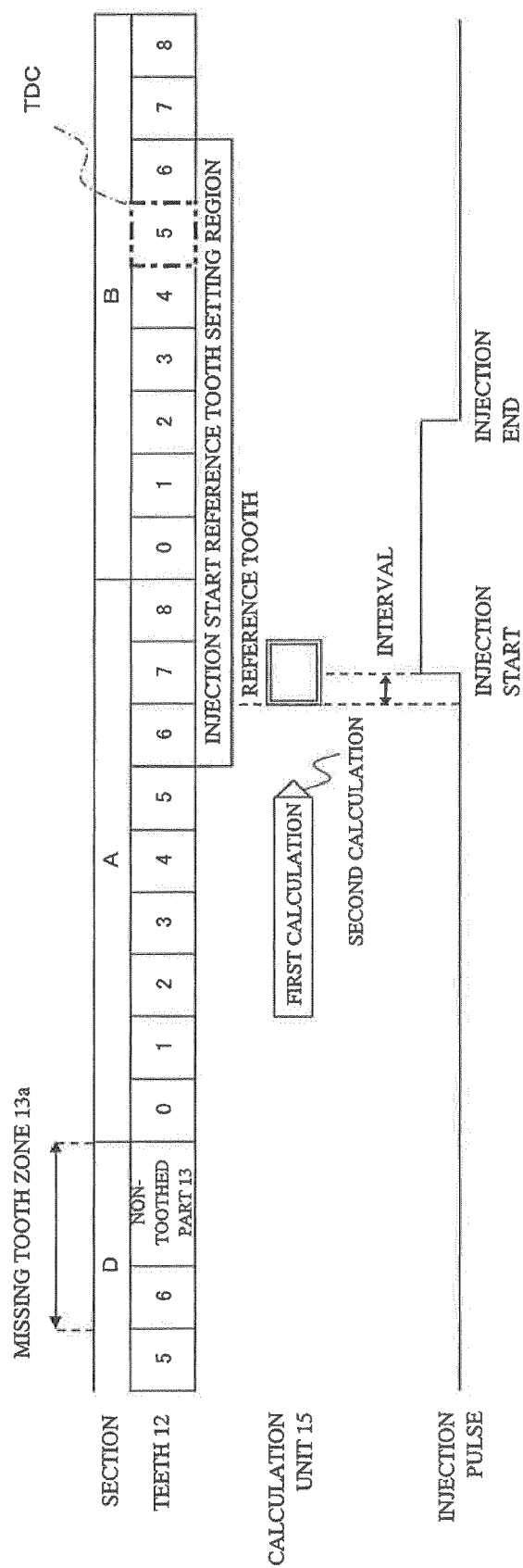


FIG.9



EUROPEAN SEARCH REPORT

Application Number
EP 12 19 9028

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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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