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(71) Applicant: **National University Corporation Tokyo University of Marine Science and Technology**
Tokyo 108-8477 (JP)

(72) Inventors:
- **OHTSU, Kohei**
  1950071 (JP)
- **ITO, Masanori**
  1350061 (JP)
- **SHIMIZU, Etsuro**
  1350044 (JP)
- **HIROSE, Noriki**
  2250011 (JP)

(74) Representative: **Müller-Boré & Partner Patentanwälte**
Grafinger Strasse 2
81671 München (DE)

(54) METHOD FOR CONTROLLING FUEL INJECTION OF MARINE DIESEL ENGINE AND DEVICE THEREFOR

(57) A method and a device for controlling fuel injection of a marine diesel engine wherein the control is exercised so as to match the loading condition at the time point of fuel injection are provided.

The method comprises: a step of measuring the fuel injection amount and the rotational speed of the marine diesel engine a prescribed number of times at prescribed time intervals and inputting the measurements, a step of evaluating a relational expression satisfying the relation between the fuel injection amount and the rotational speed of the marine diesel engine, a step of calculating the fuel injection amount (u_k) that should be injected at present according to said relational expression when the rotational speed of the marine diesel engine is set to a target rotational speed, and a step of controlling the opening of the fuel injection valve of the marine diesel engine so as to match said calculated fuel injection amount at present.

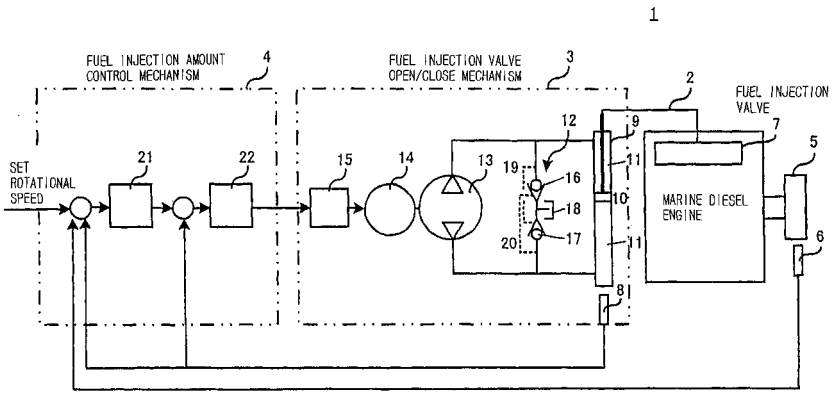

FIG. 1

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a method for controlling the fuel injection of a marine diesel engine and a device therefor.

[0002] Provided that high-load and low-load conditions periodically occur to marine diesel engines, the present invention particularly relates to a method for controlling the fuel injection of a marine diesel engine and a device therefor, wherein the fuel injection is controlled to properly match the loading condition of the marine diesel engine at the time of fuel injection so that the rotational speed of the marine diesel engine can be kept constant.

Background Art

[0003] While navigating across the ocean, ships generally meet periodic resistance affected by waves and oscillation of the hull. Consequently, the marine diesel engines are subject periodically to high-load and low-load conditions.

[0004] For a ship, unlike a road vehicle, keeping a constant rotational speed of the marine diesel engine during cruising is more preferable for the engine to keeping a constant speed.

[0005] Conventionally, fuel injection control has been exercised to provide a constant rotational speed of a marine diesel engine.

[0006] Fig. 3 shows a conventional fuel injection control device for a marine diesel engine.

[0007] As shown in Fig. 3, a conventional fuel injection control device 31 comprises a marine diesel engine 32 to be controlled, a fuel injection valve open/close mechanism 33, and a fuel injection amount control mechanism 34.

[0008] The fuel injection control device 31 is provided in the proximity of a rotating shaft 35 of the marine diesel engine 32 and comprises a first sensor 36 for detecting the rotational speed of the marine diesel engine 32, and a second sensor 38 for detecting the opening (the travel distance of the piston of a liquid pressure cylinder 39, in actuality) of a fuel injection valve 37 of the marine diesel engine 32.

[0009] The fuel injection valve open/close mechanism 33 comprises the liquid pressure cylinder 39 for driving the fuel injection valve 37, a servo mechanism 42 for providing oil pressure switchably in separated chambers 41 formed on both sides of the piston 40 of the liquid pressure cylinder 39, an oil pressure pump 43 for delivering pressurized oil, and a driver 44 for inputting a controlling signal to the servo mechanism 42.

[0010] The oil pressure pump 43 is connected to the rotating shaft 35 of the marine diesel engine 32 and is driven by a part of the dynamic force of the rotating shaft 35.

[0011] The oil pressure pump 43 is constantly rotated by the rotating shaft 35 of the marine diesel engine 32 and allows over-pressurized oil to be released from a relief valve 45 back to a tank 46 when the rotational speed of the marine diesel engine 32 is high.

[0012] The fuel injection amount control mechanism 34 comprises a first controller 47 for inputting a set rotational speed of the marine diesel engine as a target rotational speed, and the rotational speed of the marine diesel engine 32 detected by the first sensor 36, and for outputting a primary control signal for a target opening of the fuel injection valve; and a second controller 48 for inputting said primary control signal from the first controller 47, and a signal of the opening of the fuel injection valve 37 from the second sensor 38, and for outputting a secondary control signal so as to match the actual opening of the fuel injection valve 37 with the target opening of the fuel injection valve.

[0013] In the above conventional fuel injection control device 31, the first controller 47 inputs the set rotational speed and the rotational speed of the marine diesel engine detected by the first sensor 36, compares them, and outputs the primary control signal to reduce the opening of the fuel injection valve if the rotational speed of the marine diesel engine is higher than the set rotational speed, or outputs the primary control signal to enlarge the opening of the fuel injection valve if the rotational speed of the marine diesel engine is lower than the set rotational speed.

[0014] The above primary control signal is input to the servo mechanism 42 via the driver 44, and the servo mechanism 42 provides oil pressure in one of the separated chambers 41 of the liquid pressure cylinder 39 in response to the primary control signal.

[0015] The second sensor 38 detects and inputs to the second controller 48 the travel distance of the piston of the liquid pressure cylinder 39. The second controller 48 compares the opening of the fuel injection valve to a target fuel injection amount and outputs to the driver 44 of the fuel injection valve open/close mechanism 33 the secondary control signal to further open the fuel injection valve if the target opening of the fuel injection valve is not achieved, or outputs the secondary control signal to narrow the fuel injection valve when the fuel injection valve is open wider than the target opening of the fuel injection valve. As described above, in the conventional fuel injection control device for a marine diesel engine, the loading condition of the marine diesel engine is detected by the rotational speed of the marine diesel

engine, and the rotational speed is increased by enlarging the opening of the fuel injection valve if the rotational speed becomes low, or the rotational speed is limited by reducing the opening of the fuel injection valve if the rotational speed becomes high.

[0016] However, since ships periodically meet resistance on the ocean and the marine diesel engines are subject to periodic high-load and low-load conditions as previously described, with the above fuel injection control according to the conventional art there have been occasions that the conditions were already changing to the low-load conditions when the fuel injection valve was opened, or to the contrary the conditions were already changing to the high-load conditions when the fuel injection valve was narrowed.

[0017] In other words, the conventional fuel injection control over the fuel injection amount is lagged behind the actual loading condition of the marine diesel engine always providing belated fuel injection control, and the fuel efficiency is poor.

[0018] In addition, what is not preferable is the fact that shortage of the fuel injection amount despite the high-load conditions in actuality and excess of the fuel injection amount despite the low-load conditions result in applying periodic load on the components of the engine.

[0019] Moreover, the conventional art has various problems associated with the oil pressure pump being directly connected to the rotating shaft of the marine diesel engine to be driven.

[0020] The conventional fuel injection control device is configured to allow the oil pressure pump some flexibility to be driven so that the fuel injection valve can be opened when the rotational speed of the marine diesel engine is decreased.

[0021] Consequently, when the rotational speed of the marine diesel engine is increased, the oil pressure pump rotates excessively and applies high pressure, and accordingly the oil is returned to the tank through the relief valve so that the surplus pressure is escaped. That is, in the conventional fuel injection control device, the oil pressure pump periodically rotates excessively, and as a result the oil is returned to the tank through the relief valve so that the surplus pressure is escaped. As a consequence, not only the driving efficiency of the oil pressure pump is low, but also returning of high-temperature oil to the tank leads to oil deterioration, and thus the size of the tank has been increased to suppress the temperature rise.

[0022] In addition, the fuel mileage of the marine diesel engine is low because the rotating shaft of the marine diesel engine constantly drives the oil pressure pump.

[0023] In view of the above problems of the conventional art, the present invention provides a fuel injection control method and a fuel injection control device for a marine diesel engine, wherein the periodically-occurring high-load and low-load conditions of the marine diesel engine are predicted and the control is exercised so as to match the loading condition at the time point of fuel injection, in order to solve the problems.

[0024] In addition to realization of the above fuel injection control that matches the loading condition at the time point of fuel injection, the fuel injection control device of a marine diesel engine is provided to solve the problems associated with the above oil pressure pump being directly connected to the rotating shaft of the marine diesel engine.

[0025] In the Japanese Patent Laid-Open Application No. 62-26503/1987, the art of detecting the rotational speed of a marine diesel engine and multiplying the control signal for the fuel injection valve 37 by a prescribed parameter determined by said rotational speed is disclosed.

[0026] This art is provided, as a measure against the phenomenon of the excessive increase of the rotational speed of a screw propeller which is being exposed above the sea surface and running idle when weather conditions are severe, to limit the rotation of said screw propeller by said parameter.

[0027] In a Japanese utility model application (Japanese Utility Model Registration No. 63-42836/1988), a fuel injection amount adjusting device similar to the fuel injection valve open/close mechanism of the present invention is described.

SUMMARY OF THE INVENTION

[0028] The method for controlling the fuel injection of a marine diesel engine according to the present invention is characterized by comprising:

a step of measuring the fuel injection amount and the rotational speed of the marine diesel engine a prescribed number of times at prescribed time intervals and inputting the measurements,

a step of evaluating the following approximate expression satisfying the relation between the fuel injection amount and the rotational speed of the marine diesel engine measured said prescribed number of times:

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine

u: Fuel injection amount

k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied,

a step of calculating the fuel injection amount (u_k) that should be injected at present according to said approximate expression when the rotational speed of the marine diesel engine is set to a constant rotational speed, and
a step of controlling the opening of the fuel injection valve of the marine diesel engine so as to match said calculated fuel injection amount at present.

[0029] Said approximate expression can be provided by:

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots$$

a_m, b_n: coefficients.

[0030] The fuel injection control device for a marine diesel engine according to the present invention comprises:

a fuel injection valve open/close mechanism for opening and
closing a fuel injection valve of the marine diesel engine,
a fuel injection amount control mechanism for controlling the operation of said fuel injection valve open/close mechanism,
a first sensor for detecting the rotational speed of said marine diesel engine, and
a second sensor for detecting the opening of said fuel injection valve,
and said fuel injection amount control mechanism is characterized by:

inputting said rotational speed of the marine diesel engine and said
opening of the fuel injection valve from said first sensor and said second sensor respectively at prescribed time intervals,
evaluating the following approximate expression satisfying the relation between the rotational speed of the marine diesel engine measured at a prescribed number of times and the fuel injection valve:

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine
u: Fuel injection amount
k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied,

calculating the fuel injection amount (u_k) that should be injected at present according to said approximate expression when the rotational speed of the marine diesel engine is set to a constant rotational speed, and
controlling said fuel injection valve open/close mechanism so as to match the calculated fuel injection amount at present.

[0031] Said approximate expression can be provided by:

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots$$

a_m, b_n: coefficients.

[0032] Said fuel injection valve open/close mechanism can be provided by comprising:

a liquid pressure cylinder for driving the fuel injection valve,
a check valve mechanism for providing oil pressure switchably in separated chambers formed on both sides of a piston of said liquid pressure cylinder,
a bidirectional pump with a motor for delivering a pressurized fluid to said separated chambers via said check valve mechanism, and
a driver for controlling the operation of said bidirectional pump.

[0033] Said fuel injection amount control mechanism can be provided by comprising:

a first controller for inputting a set rotational speed of the marine diesel engine as a target rotational speed, the rotational speed of the marine diesel engine detected by said first sensor, and the data of the opening of the fuel injection valve detected by said second sensor, and for outputting a primary control signal for a target opening of the fuel injection valve, and
a second controller for inputting said primary control signal from the first controller, and a signal of the opening of the fuel injection valve from said second sensor, and outputting a secondary control signal so as to match the opening of the fuel injection valve with the target opening of the fuel injection valve.

[0034] In the fuel injection control method and the fuel injection control device for a marine diesel engine according to the present invention, the fuel injection amount and the rotational speed of the marine diesel engine are measured a prescribed number of times at prescribed time intervals, the measurements are input, and the relation between the fuel injection amount and the rotational speed of the marine diesel engine is determined.

[0035] The relational expression for the fuel injection amount and the rotational speed of the marine diesel engine is:

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine
u: Fuel injection amount
k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied.

Since the relational expression includes the relation between the fuel injection amount and the rotational speed of the marine diesel engine obtained a prescribed number of times (n) before the time point of the control to be applied, the control of the fuel injection amount can be exercised in consideration of the variable relation between the fuel injection amount and the rotational speed of the marine diesel engine.

[0036] That is, according to the present invention, the control of the fuel injection amount can be exercised using the relation between the fuel injection amount and rotational speed in the past so as to provide a constant rotational speed at the time point of fuel injection to match the loading condition of the marine diesel engine. In this way, the control will no longer be exercised in a manner of following after the variable loading conditions of the marine diesel engine, and the control of the fuel injection amount can be exercised efficiently.

[0037] In other words, when the hull is making repetitive rolling and pitching motions during a steady operation at sea, the condition of the screw propeller in the water is changed at constant time intervals (aging parameter), resulting in loading variation and thereby change of the rotational speed of the marine diesel engine.

[0038] With the present invention, the above change of the rotational speed is measured for a predetermined time period in relation to the fuel injection amount, the regularity of the change also being estimated, the subsequent variation cycle is predicted, and thus the control can be exercised so as to always keep a constant rotational speed of the screw propeller.

[0039] Because the fuel injection amount is properly controlled, NOx and SOx in the exhaust gas can be reduced. According to the present invention, a set rotational speed of the marine diesel engine can be kept because of the optimal fuel injection amount as described above.

[0040] In addition, according to the fuel injection control device of the present invention in which the fuel injection valve open/close mechanism comprises: a liquid pressure cylinder, a check valve mechanism for providing oil pressure switchably in separated chambers formed on both sides of a piston of said liquid pressure cylinder, a bidirectional pump with a motor for delivering a pressurized fluid to said separated chambers via said check valve mechanism, and a driver for controlling the operation of said bidirectional pump, the pump to provide oil pressure is separated from the rotating shaft of the marine diesel engine, and the fuel injection amount can thus be controlled freely irrespective of the rotational

speed of the marine diesel engine.

[0041] As a consequence, the rotational speed of the marine diesel engine at the time of fuel injection can be predicted to freely open or close the opening of the fuel injection valve as described above.

[0042] In addition, the oil pressure pump can be operated in response to the loading condition of the marine diesel engine wherein the rotation of the oil pressure pump is increased when the rotation of the marine diesel engine is in a decreased state or conversely the rotation of the oil pressure pump is decreased when the rotation of the marine diesel engine is in an increased state, and the pressurized oil from the oil pressure pump will no longer be returned unnecessarily to the tank as in the conventional art.

[0043] According to the fuel injection control device of the present invention comprising a first controller and a second controller, the difference between the control signal for the opening of the fuel injection valve and the actual opening of the fuel injection valve is reduced so that a constant rotational speed of the marine diesel engine can be kept more properly.

[0044] According to the present invention, the first controller inputs a set rotational speed of the marine diesel engine, the accrual rotational speed of the marine diesel engine, and the actual opening of the fuel injection valve, and outputs a primary control signal for the opening of the fuel injection valve.

[0045] That is, the first controller calculates the necessary opening of the fuel injection valve using the difference between the set rotational speed and the actual rotational speed of the marine diesel engine, and outputs the primary control signal using the difference between the calculated opening of the fuel injection valve and the actual opening of the fuel injection valve.

[0046] The second controller inputs the above primary control signal for the opening of the fuel injection valve, and the actual opening of the fuel injection valve, and outputs a secondary control signal for the opening of the fuel injection valve.

[0047] That is, the second controller inputs the opening of the fuel injection valve required according to the primary control signal, and the actual opening of the fuel injection valve, and outputs the secondary control signal so as to compensate the difference.

[0048] As a consequence, the control can be exercised in such a way that the difference between the opening of the fuel injection valve required according to the control signal for the fuel injection valve and the actual opening of the fuel injection valve is compensated, and a constant rotational speed of the marine diesel engine can be kept more properly according to the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049]

Fig. 1 is a block diagram showing a configuration of the fuel injection control device for a marine diesel engine according to one embodiment of the present invention.

Fig. 2 is a diagram showing a data example of the fuel injection amount stored by a first controller and the rotational speed of the marine diesel engine.

Fig. 3 is a block diagram showing a configuration of a conventional fuel injection control device for a marine diesel engine.

BEST EMBODIMENTS FOR REALIZING THE INVENTION

[0050] Embodiments of the present invention will be explained hereinafter.

[0051] Fig. 1 shows a configuration of the fuel injection control device for a marine diesel engine according to one embodiment of the present invention.

[0052] A fuel injection control device 1 in Fig. 1 comprises a marine diesel engine 2 to be controlled, a fuel injection valve open/close mechanism 3, and a fuel injection amount control mechanism 4.

[0053] As a sensor system, the fuel injection control device 1 is provided in the proximity of a rotating shaft 5 of the marine diesel engine 2, and comprises a first sensor 6 for detecting the rotational speed of the marine diesel engine 2, and a second sensor 8 for detecting the opening of a fuel injection valve 7 of the marine diesel engine 2. Preferably the second sensor 8 is made to detect the opening of the fuel injection valve 7 indirectly by detecting the travel distance of the piston of the liquid pressure cylinder of the fuel injection valve open/close mechanism 3 rather than detecting the opening of the fuel injection valve 7 directly, as will be described later. The fuel injection valve open/close mechanism 3 comprises a liquid pressure cylinder 9 for driving the fuel injection valve 7; a check valve mechanism 12 for providing oil pressure switchably in separated chambers 11 formed on both sides of a piston 10 of the liquid pressure cylinder 9; a bidirectional pump 13 for delivering a pressurized working fluid to the separated chambers 11 via the check valve mechanism 12; a motor 14 for driving the bidirectional pump 13; and a driver 15 for controlling the operation of the bidirectional pump 13 and the motor 14.

[0054] In the present embodiment, the second sensor 8 detects the travel distance of the piston 10 of the liquid pressure cylinder 9 instead of directly detecting the opening of the fuel injection valve 7.

[0055] In the check valve mechanism 12, two check valves 16 and 17 are positioned, a pipe linking therebetween, so that the flow direction allowed by each valve is opposite to each other, and another pipe is provided to direct the working fluid, flown out to the former pipe, to a tank 18.

[0056] From the pipeline on the upstream side of one of the check valves 16 and 17 to the other check valve, pipes 19 and 20 are provided respectively to direct the pressurized fluid to push up (open) the other check valve.

[0057] The fuel injection amount control mechanism 4 comprises: a first controller 21 for inputting a set rotational speed of the marine diesel engine as a target rotational speed, the rotational speed of the marine diesel engine 2 detected by the first sensor 6, and the data of the opening of the fuel injection valve 7 detected by the second sensor 8, and for outputting a primary control signal for a target opening of the fuel injection valve; and a second controller 22 for inputting said primary control signal from the first controller 21, and a signal of the opening of the fuel injection valve 7 from the second sensor 8, and outputting a secondary control signal so as to match the actual opening of the fuel injection valve 7 with the target opening of the fuel injection valve.

[0058] The control exercised by the secondary control signal in addition to the primary control signal allows the opening of the fuel injection valve to be exactly matched with the target opening of the fuel injection valve by the second sensor 8 detecting the actual travel distance of the piston of the liquid pressure cylinder 9, whereas if the primary control signal inputs to the driver 15 of the fuel injection valve open/close mechanism 3 the target fuel injection amount, i.e. the control signal for the opening of the fuel injection valve 7, it would be difficult to control the exact opening of the fuel injection valve 7 solely by the rotation of the bidirectional pump 13.

[0059] The operation of the fuel injection valve open/close mechanism 3 is as follows.

[0060] The control signal from the driver 15 allows the motor 14 to run, such as starting, stopping, and rotating in the normal/reverse direction. Here an explanation will be made by exemplifying the case where the pressurized working fluid is delivered to the upper chamber of the separated chambers 11 of the liquid pressure cylinder 9 in Fig. 1. The bidirectional pump 13 is driven by the motor 14 to draw the working fluid from the tank 18 and deliver the pressurized working fluid to the pipe system on the upstream side of the check valve 16. From the pipe system on the upstream side of the check valve 16, the pressurized working fluid flows into the upper chamber of the separated chambers 11 of the liquid pressure cylinder 9 and pushes down the piston 10. The pressurized working fluid in the pipe system on the upstream side of the check valve 16 is made to pass at the same time through the pipe 19 and push up the valve body of the check valve 17 to open the check valve 17. With the piston 10 being pushed down, the working fluid in the lower chamber of the separated chambers 11 of the liquid pressure cylinder 9 flows out to the pipe system on the upstream side of the check valve 17. Since the check valve 17 is open, the working fluid which has flowed out to the pipe system on the upstream side of the check valve 17 flows out to the tank 18 through the check valve 17.

[0061] The reverse of the above operations takes place in the case where the pressurized working fluid is delivered to the lower chamber of the separated chambers 11 of the liquid pressure cylinder 9.

[0062] By the travel of the piston 10, the fuel injection valve 7 is opened or closed via the rod of the piston 10.

[0063] Explained next is the fuel injection control, i.e. a method for controlling the fuel injection so as to match the loading condition of the marine diesel engine at the time of fuel injection, according to the present invention.

[0064] The fuel injection control device 1 measures the fuel injection amount and the rotational speed of the marine diesel engine a prescribed number of times at prescribed time intervals and inputs the measurements. The data of the aforementioned fuel injection amount and rotational speed of the marine diesel engine are collected by the first sensor 6 and the second sensor 8. The data of the fuel injection amount and the rotational speed of the marine diesel engine are corresponded to each other, as shown in Fig. 2 for example, and stored in a storage device, not shown, of the first controller 21.

[0065] The relation between the fuel injection amount, u, and the rotational speed of the marine diesel engine, *y,* is expected to satisfy the following formula.

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine
u: Fuel injection amount
k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied

The above relational expression *G* shows that the rotational speed of the marine diesel engine at the time (time point)

of control to be applied is defined by the previous rotational speed of the marine diesel engine, the fuel injection amount in the past, and the fuel injection amount at present.

[0066] At this point, the following relational expression is expected to represent an example of the relational expression *G*.

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots$$

a_m, b_n: Coefficients

[0067] By determining the coefficients *a*, *b,* the rotational speed of the marine diesel engine due to the fuel injection amount at present can be determined.

[0068] The coefficients *a, b* not only depend on the marine diesel engine but also change according to the loading conditions of the marine diesel engine. Accordingly, the first controller 21 of the fuel injection control device 1 calculates the above coefficients *a, b* while inputting the fuel injection amount and the rotational speed of the marine diesel engine as needed.

[0069] By assigning the fuel injection amount, *u,* and the rotational speed, *y,* of the marine diesel engine, shown in Fig. 2, to the above relational expression, a plurality of expressions,

$$\begin{aligned} y_k &= a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + \cdots \\ y_{k+1} &= a_1 y_k + a_2 y_{k-1} + \cdots + b_0 u_{k+1} + b_1 u_k + \cdots \\ y_{k+2} &= a_1 y_{k+1} + a_2 y_k + \cdots + b_0 u_{k+2} + b_1 u_{k+1} + \cdots \\ &\vdots \end{aligned}$$

,

are obtained as time passes. From these expressions, a matrix,

$$\mathrm{Y} = \begin{bmatrix} y_k \\ y_{k+1} \\ y_{k+2} \\ \vdots \end{bmatrix} = \begin{bmatrix} y_{k-1} & y_{k-2} & \cdots & u_k & u_{k-1} & \cdots \\ y_k & y_{k-1} & \cdots & u_{k+1} & u_k & \cdots \\ y_{k+1} & y_k & \cdots & u_{k+2} & u_{k+1} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ b_0 \\ b_1 \\ \vdots \end{bmatrix} = \mathrm{X}\,\mathrm{A}$$

,

is obtained. After sufficient time passes, the coefficient matrix *A* is determined as follows.

$$\mathrm{A} = \left(\mathrm{X}^T \mathrm{X}\right)^{-1} \mathrm{X}^T \mathrm{Y}$$

[0070] Once the coefficient matrix *A* is determined, the relation between the fuel injection amount at present and the rotational speed of the marine diesel engine due to the fuel injection amount at present is obtained from the expression,

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots ,$$

and by designating the rotational speed of the marine diesel engine as a set rotational speed as a target, the injection amount that should be injected at present is determined.

[0071] According to the present invention, an appropriate fuel amount for the loading condition of the marine diesel engine at the time of fuel injection can be injected by exercising the fuel injection amount control that will no longer be lagged behind the actual loading condition of the marine diesel engine as the conventional fuel injection control is, and the rotational speed of the marine diesel engine can be efficiently kept at a target rotational speed, and also unstable behaviors of the engine caused by opening and closing the fuel injection valve behind the actual loading condition can be prevented. Because a proper amount of fuel can be injected, NOx and SOx in the exhaust gas from a marine diesel engine can be reduced according to the present invention.

[0072] In addition, the oil pressure pump of the fuel injection valve open/close mechanism can be driven with a proper dynamic force due to the oil pressure pump of the fuel injection valve open/close mechanism being separated from the rotating shaft of the marine diesel engine, and returning of the working fluid from the relief valve back to the tank in order to release a surplus pressure as in the conventional fuel injection control devices can be prevented, and also compactification of fuel injection control devices can be achieved, according to the present invention.

Claims

1. A method for controlling the fuel injection of a marine diesel engine comprising:

a step of measuring the fuel injection amount and the rotational speed of the marine diesel engine a prescribed number of times at prescribed time intervals and inputting the measurements,
a step of evaluating the following approximate expression satisfying the relation between the fuel injection amount and the rotational speed of the marine diesel engine measured said prescribed number of times:

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine
u: Fuel injection amount
k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied,

a step of calculating the fuel injection amount (u_k) that should be injected at present according to said approximate expression when the rotational speed of the marine diesel engine is set to a constant rotational speed, and
a step of controlling the opening of the fuel injection valve of the marine diesel engine so as to match said calculated fuel injection amount at present.

2. A method for controlling the fuel injection of a marine diesel engine according to Claim 1 **characterized in that** said approximate expression is provided by:

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots$$

a_m, b_n: coefficients.

3. A fuel injection control device for a marine diesel engine comprising:

a fuel injection valve open/close mechanism for opening and closing a fuel injection valve of the marine diesel engine,

a fuel injection amount control mechanism for controlling the operation of said fuel injection valve open/close mechanism,
a first sensor for detecting the rotational speed of said marine diesel engine, and
a second sensor for detecting the opening of said fuel injection valve,
said fuel injection amount control mechanism **characterized by**:

inputting said rotational speed of the marine diesel engine and said opening of the fuel injection valve from said first sensor and said second sensor respectively at prescribed time intervals,
evaluating the following approximate expression satisfying the relation between the rotational speed of the marine diesel engine measured at a prescribed number of times and the fuel injection valve:

$$y_k = G(y_i, u_j) \quad (i = k-1, \cdots, k-n, \quad j = k, \cdots, k-n)$$

y: Rotational speed of the marine diesel engine
u: Fuel injection amount
k: Time (time point) of the control to be applied
n: Number of times of the previous measurements of the rotational speed of the marine diesel engine and the fuel injection amount to be used for the calculation at the time of the control to be applied,

calculating the fuel injection amount (u_k) that should be injected at present when the rotational speed of the marine diesel engine in said approximate expression is set to a constant rotational speed, and
controlling said fuel injection valve open/close mechanism so as to match the calculated fuel injection amount at present.

4. A fuel injection control device for a marine diesel engine according to Claim 3 **characterized in that** said approximate expression is:

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \cdots + b_0 u_k + b_1 u_{k-1} + b_2 u_{k-2} + \cdots$$

a_m, b_n: coefficients.

5. A fuel injection control device for a marine diesel engine according to Claims 3 or 4 **characterized in that** said fuel injection valve open/close mechanism comprises:

a liquid pressure cylinder for driving the fuel injection valve,
a check valve mechanism for providing oil pressure switchably in separated chambers formed on both sides of a piston of said liquid pressure cylinder,
a bidirectional pump with a motor for delivering a pressurized fluid to said separated chambers via said check valve mechanism, and
a driver for controlling the operation of said bidirectional pump.

6. A fuel injection control device for a marine diesel engine according to any one of Claims 3 to 5 **characterized in that** said fuel injection amount control mechanism comprises:

a first controller for inputting a set rotational speed of the marine diesel engine as a target rotational speed, the rotational speed of the marine diesel engine detected by said first sensor, and the data of the opening of the fuel injection valve detected by said second sensor, and for outputting a primary control signal for a target opening of the fuel injection valve, and
a second controller for inputting said primary control signal from the first controller, and a signal of the opening of the fuel injection valve from said second sensor, and outputting a secondary control signal so as to match the opening of the fuel injection valve with the target opening of the fuel injection valve.

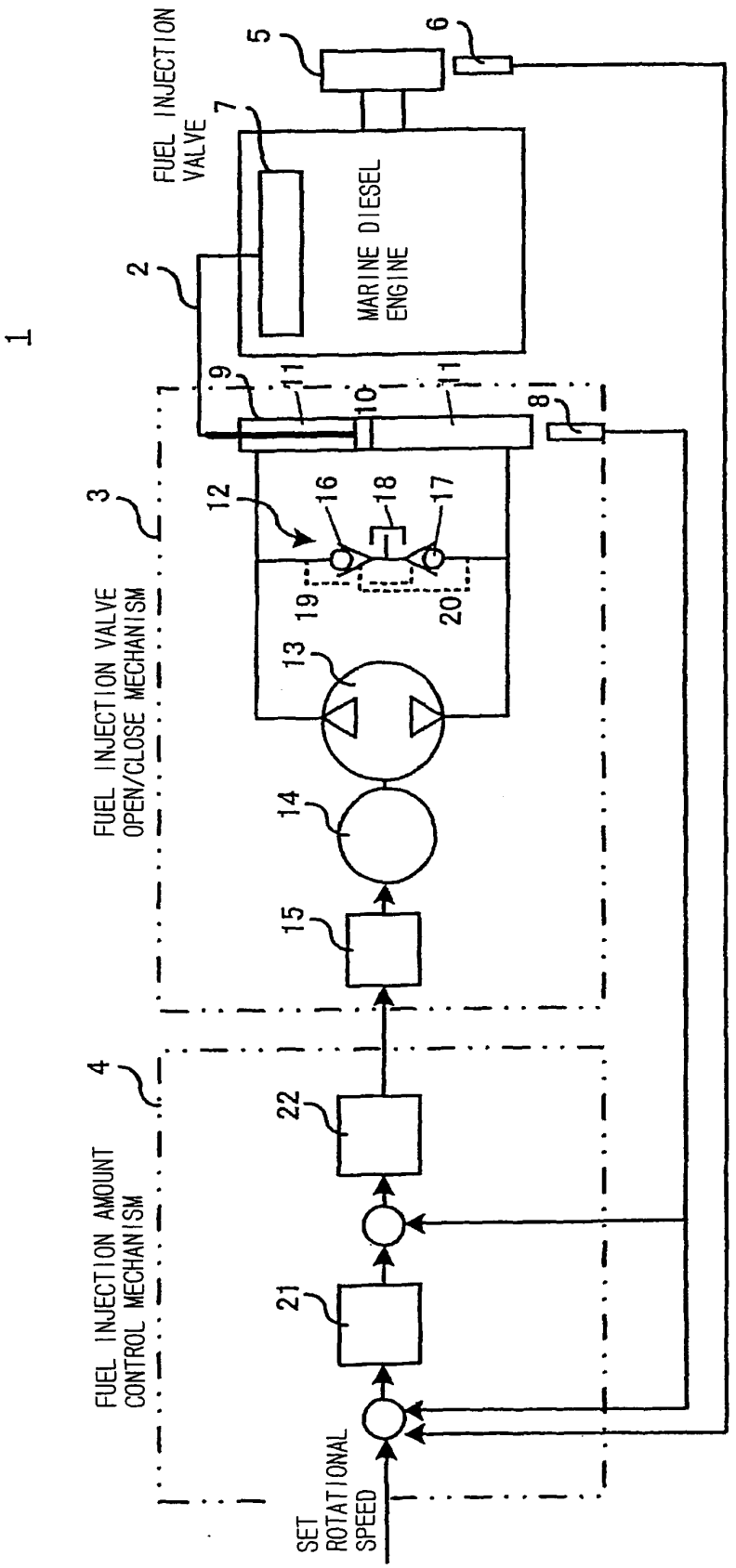
1
FUEL INJECTION VALVE
MARINE DIESEL ENGINE
FUEL INJECTION VALVE OPEN/CLOSE MECHANISM
FUEL INJECTION AMOUNT CONTROL MECHANISM
SET ROTATIONAL SPEED
2
3
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FIG. 1

FUEL INJECTION AMOUNT (OPENING OF THE FUEL INJECTION VALVE)	ROTATIONAL SPEED OF THE MARINE DIESEL ENGINE
u_1	y_1
u_2	y_2
u_3	y_3
u_4	y_4
u_5	y_5
⋮	⋮

FIG. 2

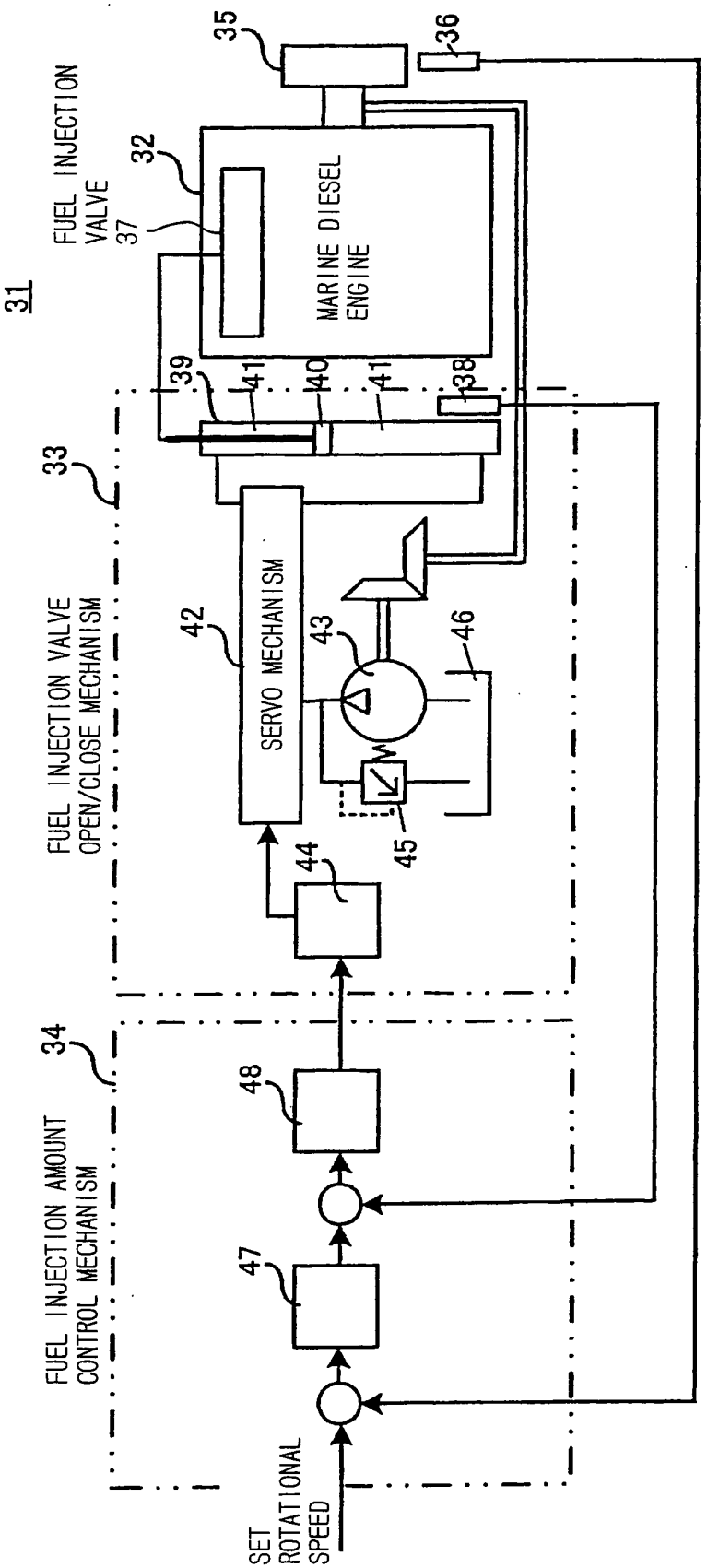
31
FUEL INJECTION AMOUNT CONTROL MECHANISM
34
FUEL INJECTION VALVE OPEN/CLOSE MECHANISM
33
FUEL INJECTION VALVE
37
32
MARINE DIESEL ENGINE
35
36
39
41
40
41
38
SERVO MECHANISM
42
43
46
45
44
48
47
SET ROTATIONAL SPEED

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020305

A. CLASSIFICATION OF SUBJECT MATTER
F02D41/04(2006.01), ***F02D29/02***(2006.01), ***F02M37/08***(2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D41/04(2006.01), ***F02D29/02***(2006.01), ***F02M37/08***(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005
Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 62-17345 A (Mitsubishi Heavy Industries, Ltd.), 26 January, 1987 (26.01.87), All pages; Figs. 1 to 6 (Family: none)	1-6
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 107911/1984(Laid-open No. 25559/1986) (Nippon Air Brake Co., Ltd.), 15 February, 1986 (15.02.86), Full text; Figs. 1 to 4 (Family: none)	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 December, 2005 (21.12.05)	10 January, 2006 (10.01.06)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020305

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 62-26503 A (NKK Corp.), 04 February, 1987 (04.02.87), Full text; Figs. 1 to 3 (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 62026503 A **[0025]**
- JP 63042836 U **[0027]**