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(54) SHIP PROPULSION SYSTEM

(57) Provided is a ship propulsion system (1) including a variable pitch propeller (15) including a pitch change mechanism (16), a gas engine (2) including a plurality of cylinders (21), for rotating the propeller (15), a plurality of fuel injection valves (5) provided to the gas engine (2), corresponding to the cylinders (21), respectively, and a control device (6) for controlling the mechanism (16) and the valves (5). When a misfire occurs continuously in any of the cylinders (21), the control device (6) suspends fuel gas injection from the fuel injection valve (5) corresponding to the misfired cylinder (21) and lowers a limit of a fuel injection amount of other fuel injection valves (5), and reduces a pitch of the propeller (15). The ship propulsion system (1) maintains the output of the gas engine after a cylinder cutoff as high as possible without lowering the efficiency during a normal operation.

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Description

Technical Field

[0001] The present disclosure relates to a ship propulsion system including a gas engine.

Background

[0002] In recent years, as disclosed in JP2014-177918A, ship propulsion systems including a gas engine have been developed in terms of crude-oil resource amount problem, emission control problem, etc. A supercharger (or a turbocharger) is typically mounted on the gas engine.

[0003] As illustrated in Fig. 5, the gas engine has a knock range and a misfire range in a relation between an air-fuel ratio (excess air ratio) and a brake mean effective pressure (BMEP). That is, the gas engine at a high load is operable in a narrow range between the knock range and the misfire range.

[0004] The misfire may also occur in the gas engine due to reasons other than the air-fuel ratio, such as wear of ignition plugs and abnormalities of ignition coils. In such a case, the misfire continuously occurs over a plurality of cycles. If the continuous misfire occurs in any of the cylinders of the gas engine, it may be desirable to suspend an injection of fuel gas from a fuel injection valve corresponding to the cylinder (i.e., a cylinder cutoff). This prevents unburnt fuel gas from being discharged.

[0005] Here, in order to suppress a reduction in the output of the gas engine caused by the cylinder cutoff, it may be desirable to increase injection amounts of the fuel gas into other cylinders. However, if an air amount fed to each cylinder from a compressor of the supercharger cannot be increased, an operating point may shift into the knock range as illustrated by an arrow X in Fig. 5 as the injection amount of the fuel gas is increased. In addition, since the fuel gas will not be burnt in the cylinder where the misfire continuously occurs, energy of exhaust gas which is discharged from the gas engine and fed to a turbine of the supercharger is reduced. Thus, air fed to the gas engine from the compressor of the supercharger decreases. Therefore, in other cylinders, the injection amounts of the fuel gas cannot be increased, and, conversely, it is necessary to reduce the injection amounts of the fuel gas. For this reason, after the cylinder cutoff, the output of the gas engine may fall greatly, and in order to enable a continuous operation, it is necessary to determine the specification of the supercharger in consideration of the cylinder cutoff. For example, the specification of the supercharger may be determined such that an air amount sufficiently greater than the air amount needed for a normal operation of the compressor of the supercharger is discharged therefrom and, during the normal operation, the excessive air discharged from the compressor is allowed to escape to the atmosphere. In that case, the normal operation efficiency is lowered.

Summary

[0006] One purpose of the present disclosure is to provide a ship propulsion system which maintains an output of a gas engine as high as possible after a cylinder cutoff, without lowering efficiency during a normal operation.

[0007] In order to achieve the purpose, a ship propulsion system according to one aspect of the present disclosure includes a variable pitch propeller including a pitch change mechanism, a gas engine including a plurality of cylinders, for rotating the propeller, a plurality of fuel injection valves provided to the gas engine, corresponding to the plurality of cylinders, respectively, and a control device for controlling the pitch change mechanism of the propeller, and the plurality of fuel injection valves. When a misfire occurs continuously in any of the plurality of cylinders, the control device suspends an injection of fuel gas from the fuel injection valve corresponding to the misfired cylinder and lowers a limit of a fuel injection amount of other fuel injection valves, and reduces a pitch of the propeller.

[0008] According to this structure, since the injection amount of the fuel gas is large at a high load, the injection amount of the fuel gas is reduced by lowering the limit of the fuel injection amount. Thus, an engine speed of the gas engine once drops; however, since the pitch of the variable pitch propeller can be reduced, the engine speed of the gas engine increases by the reduced amount. Therefore, since energy of exhaust gas discharged from the gas engine per unit time increases, it is possible to increase air fed to the gas engine from a compressor of a supercharger. As a result, the injection amount of the fuel gas is increased. Accordingly, the output of the gas engine is maintained as high as possible after a cylinder cutoff. In addition, since the specification of the supercharger can be determined without taking the cylinder cutof into consideration, the efficiency during the normal operation will not be lowered.

[0009] The limit may be a first limit, and the control device may determine a second limit of the fuel injection amount of the plurality of fuel injection valves based on temperature and pressure of air fed to the gas engine, and an actual engine speed of the gas engine, and may use one of the first limit and the second limit that is smaller than the other, as the limit. According to this structure, a shift of an operating point to a knock range is certainly prevented.

[0010] The control device may perform a PID control of the plurality of fuel injection valves so that an actual engine speed of the gas engine is adjusted to a target engine speed, and when the continuous misfire occurs in any of the plurality of cylinders, the control device may raise the target engine speed with a rated engine speed being used as an upper limit thereof. According to this structure, the output of the gas engine is maintained at a higher level.

[0011] For example, the ship propulsion system may further include a plurality of pressure gauges for measuring pressures in the plurality of cylinders, respectively. The control device may determine per cycle based on the measurements of the pressure gauges whether a misfire occurs in each of the plurality of cylinders.

[0012] A ratio of the lowered limit of the fuel injection amount with respect to a maximum fuel injection amount of each of the fuel injection valves may be a value that is 10% or more less than (T-M)/T, where the total number of cylinders is T and the number of cylinders where the continuous misfire occurs is M. According to this structure, a knock is effectively controlled.

Effects

[0013] According to the present disclosure, the output of the gas engine is maintained as high as possible after the cylinder cutoff, without lowering the efficiency during the normal operation.

Brief Description of Drawings

[0014] The present disclosure is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings, in which like reference numerals indicate like elements and in which:

Fig. 1 is a view schematically illustrating a configuration of a ship propulsion system according to one embodiment of the present disclosure;
Fig. 2 is a graph illustrating a relation between an engine speed and an output of a gas engine;
Fig. 3 is a graph illustrating a relation between an air amount, and a second limit of a fuel injection amount;
Fig. 4 is a graph illustrating a change in the injection amount of the fuel gas with time; and
Fig. 5 is a graph illustrating a knock range and a misfire range of the gas engine during a lean-burn operation, where the horizontal axis indicates an air-fuel ratio and the vertical axis indicates a brake mean effective pressure (BMEP).

Detailed Description

[0015] A ship propulsion system 1 according to one embodiment of the present disclosure is illustrated in Fig. 1. This system 1 includes a variable pitch propeller 15, and a gas engine 2 which rotates the propeller 15. A supercharger 11 is mounted on the gas engine 2. Note that the supercharger 11 is illustrated separately from the gas engine 2 in order to facilitate understandings in Fig. 1.

[0016] The propeller 15 includes a pitch change mechanism 16 which changes a pitch P of the propeller 15 (i.e., an angle of propeller blades). In this embodiment, the gas engine 2 is coupled to the propeller 15 via a transmission 14 to directly rotate the propeller 15. Note that, although illustration is omitted, the propeller 15 may be coupled to an electric motor via the transmission 14, the gas engine 2 may be coupled to a power generator, and the gas engine 2 may indirectly rotate the propeller 15 via the power generator and the electric motor.

[0017] In this embodiment, the gas engine 2 is a four-stroke engine. Note that the gas engine 2 may be a two-stroke engine. Alternatively, the gas engine 2 may be a single-fuel gas engine which burns only fuel gas or gaseous fuel (e.g., natural gas), or may be a dual-fuel engine which bums one or both of gaseous fuel and liquid fuel.

[0018] For example, the gas engine 2 includes a plurality of in-line cylinders 21 which are arranged parallel to axial directions of a crankshaft (not illustrated). For example, the number of cylinders 21 is 5 to 18 (only three cylinders are illustrated in order to simplify the illustration in Fig. 1).

[0019] A piston (not illustrated) is fitted into each cylinder 21. If the gas engine 2 is a four-stroke engine, one cycle of the gas engine 2 is performed in each cylinder 21 by the piston reciprocating twice (i.e., intake, compression, expansion, and exhaust). A phase angle (0° to 720°) of the gas engine 2 during one cycle of each cylinder 21 is detected by a phase angle detector 7. The phase angle may be detected based on a rotation angle of the crankshaft (crank angle), a position of the piston, etc. For example, the phase angle detector 7 is an electromagnetic pickup, a proximity switch, or a rotary encoder. The phase angle detector 7 also detects an actual engine speed N of the gas engine 2.

[0020] The cylinder 21 is connected with a compressor 12 and a turbine 13 of the supercharger 11 via an intake passage 3 and an exhaust passage 4, respectively. The intake passage 3 leads air discharged from the compressor 12 to the cylinders 21, and the exhaust passage 4 leads exhaust gas discharged from the cylinders 21 to the turbine 13. In more detail, the intake passage 3 includes an intake manifold 32, a primary passage 31 which connects the intake manifold 32 with the compressor 12, and a plurality of branch passages 33 which connect the intake manifold 32 with the cylinders 21, respectively. The exhaust passage 4 includes an exhaust manifold 42, a plurality of branch passages 41 which connect the cylinders 21 to the exhaust manifold 42, and a primary passage 43 which connects the exhaust manifold 42 with the turbine 13.

[0021] An intake blowoff passage 17 is connected with the intake passage 31, and a flow control valve 18 is provided in the intake blowoff passage 17. An amount of air introduced into the cylinders 21 is controllable by operating the flow control valve 18. Note that, although illustration is omitted, the amount of air introduced into the cylinders 21 may also be controlled by connecting an exhaust blowoff passage with the exhaust passage 43, and operating a flow control valve provided in the exhaust blowoff passage.

[0022] A plurality of fuel injection valves 5 which respectively correspond to the cylinders 21 are provided in the gas engine 2. Each fuel injection valve 5 injects fuel gas into air which is fed into the corresponding cylinder

21.

[0023] The pitch change mechanism 16 of the propeller 15 and the fuel injection valve 5 which are described above are controlled by a control device 6, for example, based on an operated amount of the ship telegraph (not illustrated) which is a lever to change a ship traveling speed by being operated. As illustrated in Fig. 2, when the pitch P of the propeller 15 is a particular value 01, a relation between an engine speed and an output of the gas engine 2 draws a curve C1. When the fuel gas is injected by a maximum injection amount Qm from each fuel injection valve 5, a torque of the gas engine 2 becomes 100% (the output is 100%), and the engine speed becomes a maximum engine speed Nm.

[0024] The control device 6 performs a PID control of the fuel injection valve 5 so that an actual engine speed N of the gas engine 2 is adjusted to a target engine speed NT. The target engine speed NT is determined, for example, according to the operated amount of the ship telegraph.

[0025] Returning to Fig. 1, pressure gauges 83 which measure pressures inside the cylinders 21 are provided to the cylinders 21, respectively. The control device 6 determines per cycle whether a misfire occurs in each cylinder 21 based on the measurement of the corresponding pressure gauge 83, respectively. For example, the control device 6 calculates a difference of the pressures inside the cylinder 21 before and after a top dead center, and determines that the misfire occurs when the difference is below a threshold.

[0026] In this embodiment, a thermometer 81 and a pressure gauge 82 are provided in the primary passage 31 of the intake passage 3 described above. The thermometer 81 and the pressure gauge 82 measure a temperature and a pressure of air which is fed to the cylinders 21, respectively. The temperature and the pressure which are respectively measured by the thermometer 81 and the pressure gauge 82 arc inputted into the control device 6.

[0027] As illustrated in Fig. 4, for each fuel injection valve 5, a first limit L1 of the fuel injection amount according to the number of cylinders 21 where the maximum injection amount Qm described above and the continuous misfire occur, and a second limit L2 of the fuel injection amount according to the air amount fed to each cylinder 21 are defined. The control device 6 uses one of the first limit L1 and the second limit L2 which is smaller than the other.

[0028] In this embodiment, the first limit L1 in a normal operation (i.e., when a cylinder cutoff is not performed or when the number of cylinders 21 where the continuous misfire occurs is zero) is set to a value $\alpha 1$ greater than the maximum injection amount Qm so that an excessive output is prevented. For example, various limits L1 are defined beforehand according to the engine speed and stored in the control device 6 in the form of a map. Note that the first limit L1 in the normal operation may be equal to the maximum injection amount Qm.

[0029] The first limit L1 when the cylinder cutoff is performed (i.e., when the number of cylinders 21 where the continuous misfire occurs is one or more) is set to a value $\alpha 2$ sufficiently less than the value $\alpha 1$. For example, a ratio of $\alpha 2$ with respect to the maximum injection amount Qm (i.e., $\alpha 2$/Qm) is a value 10% or more less than (T-M)/T, where the total number of cylinders 21 is T and the number of cylinders 21 where the continuous misfire occurs is M. It was confirmed by experiments that a knock is easy to occur when $\alpha 2$/Qm is a value near (T-M)/T, but the knock is effectively prevented when $\alpha 2$/Qm is a value 10% or more less than (T-M)/T. For example, when T= 6 and M= 1, (T-M)/T is about 83% and $\alpha 2$/Qm is about 60%.

[0030] The air amount fed to the cylinders 21 which is used as the basis of the second limit L2 is calculated based on the temperature and the pressure of the air fed to the gas engine 2, and the actual engine speed N of the gas engine 2. Thus, the control device 6 determines the second limit L2 of the fuel injection valves 5 based on the temperature and the pressure measured by the thermometer 81 and the pressure gauge 82, respectively, and the actual engine speed N detected by the phase angle detector 7.

[0031] When the continuous misfire occurs in any of the cylinders 21 over a plurality of cycles (e.g., four cycles), the control device 6 suspends the injection of the fuel gas from the fuel injection valve 5 corresponding to the cylinder 21, and lowers the first limit L1 of the fuel injection amount of other fuel injection valves 5.

[0032] For example, before the continuous misfire occurs, the operating state is at a high load as illustrated by Point A in Fig. 2 and, thus, it is assumed that the fuel gas is injected from each fuel injection valve 5 by an injection amount Qc, as illustrated in Fig. 4. Here, the first limit L1 is $\alpha 1$ which is greater than the maximum injection amount Qm. The control device 6 lowers the first limit L1 from $\alpha 1$ to $\alpha 2$, when the continuous misfire occurs in any of the cylinders 21.

[0033] Since the injection amount of the fuel gas is in a high state (i.e., more injection amount) at the high load, the injection amount of the fuel gas is reduced by the lowering of the first limit L1 as illustrated in Fig. 4. Thus, as illustrated in Fig. 2, the operating state transits to Point B from Point A along the curve C1, and the engine speed of the gas engine 2 once drops. In addition, when the continuous misfire occurs, energy of exhaust gas discharged from the gas engine 2 decreases, and the air amount fed to the cylinders 21 is reduced. As a result, as illustrated in Fig. 4, the injection amount of the fuel gas is regulated by the second limit L2, and becomes significantly less than the first limit L1.

[0034] Accordingly, the control device 6 reduces the pitch P of the propeller 15 when the continuous misfire occurs ($\theta 1 \rightarrow \theta 2$), as illustrated in Fig. 2. For example, 02 is 60% to 80% of $\theta 1$. Thus, the operating state is shifted to Point C on a curve C2 which is below the curve C1 and, thus, the engine speed of the gas engine 2 increases by the reduced amount of the pitch P of the propeller 15. Since the energy of exhaust gas per unit time, discharged from the gas engine 2 thus increases, it is possible to increase the air fed to the gas engine 2 from the compressor 12 of the supercharger 11. As a result, the injection amount of the fuel gas is increased to be brought closer to the first limit L1 ($\alpha 2$), as illustrated in Fig. 4. After that, the operating state transits to Point D along a torque line which is defined by the first limit L1 ($\alpha 2$), and the actual engine speed N turns into the target engine speed NT.

[0035] As described above, the ship propulsion system 1 of this embodiment maintains the output of the gas engine 2 as high as possible after the cylinder cutoff, as illustrated by Point D in Fig. 2. In addition, since the specification of the supercharger 11 is defined without taking the cylinder cutoff into consideration, the efficiency in the normal operation will not be lowered.

[0036] In a case where the continuous misfire occurs in any of the cylinders 21, if a control is performed only based on the second limit L2 without the first limit L1 being instantly lowered, the detection of the reduction of the air amount fed to the cylinder 21 is delayed due to the time lag, resulting in knocks. On the other hand, in this embodiment, since the first limit L1 is instantly lowered, knocks are prevented.

[0037] In addition, in this embodiment, since one of the first limit L1 and the second limit L2 which is smaller than the other is used, the shift of the operating point into the knock range is prevented certainly.

[0038] It is desirable for the control device 6 to raise the target engine speed NT with a rated engine speed being used as an upper limit thereof, when the continuous misfire occurs in any of the cylinders 21. According to this configuration, the output of the gas engine 2 is maintained even higher.

(Modifications)

[0039] Various modifications may be made to the present invention within the spirit and scope of the present invention, without being limited to the embodiment described above.

Claims

1. A ship propulsion system (1), comprising:

a variable pitch propeller (15) including a pitch change mechanism (16);
a gas engine (2) including a plurality of cylinders (21), for rotating the propeller (15);
a plurality of fuel injection valves (5) provided to the gas engine (2), corresponding to the plurality of cylinders (21), respectively; and
a control device (6) for controlling the pitch change mechanism (16) of the propeller (15), and the plurality of fuel injection valves (5),
wherein, when a misfire occurs continuously in any of the plurality of cylinders (21), the control device (6) suspends an injection of fuel gas from the fuel injection valve (5) corresponding to the misfired cylinder (21) and lowers a limit of a fuel injection amount of other fuel injection valves (5), and reduces a pitch of the propeller (15).

2. The ship propulsion system (1) of claim 1, wherein, the limit is a first limit, and
the control device (6) determines a second limit of the fuel injection amount of the plurality of fuel injection valves (5) based on temperature and pressure of air fed to the gas engine (2), and an actual engine speed of the gas engine (2), and uses one of the first limit and the second limit that is smaller than the other, as the limit.

3. The ship propulsion system (1) of claim 1 or 2, wherein the control device (6) performs a PID control of the plurality of fuel injection valves (5) so that an actual engine speed of the gas engine (2) is adjusted to a target engine speed, and when the continuous misfire occurs in any of the plurality of cylinders (21), the control device (6) raises the target engine speed with a rated engine speed being used as an upper limit thereof.

4. The ship propulsion system (1) of any one of claims 1 to 3, further comprising a plurality of pressure gauges (83) for measuring pressures in the plurality of cylinders (21), respectively,
wherein the control device (6) determines per cycle based on the measurements of the pressure gauges (83) whether a misfire occurs in each of the plurality of cylinders (21).

5. The ship propulsion system (1) of any one of claims 1 to 4, wherein a ratio of the lowered limit of the fuel injection amount with respect to a maximum fuel injection amount of each of the fuel injection valves (5) is a value that is 10% or more less than (T-M)/T, where the total number of cylinders (21) is T and the number of cylinders (21) where the continuous misfire occurs is M.

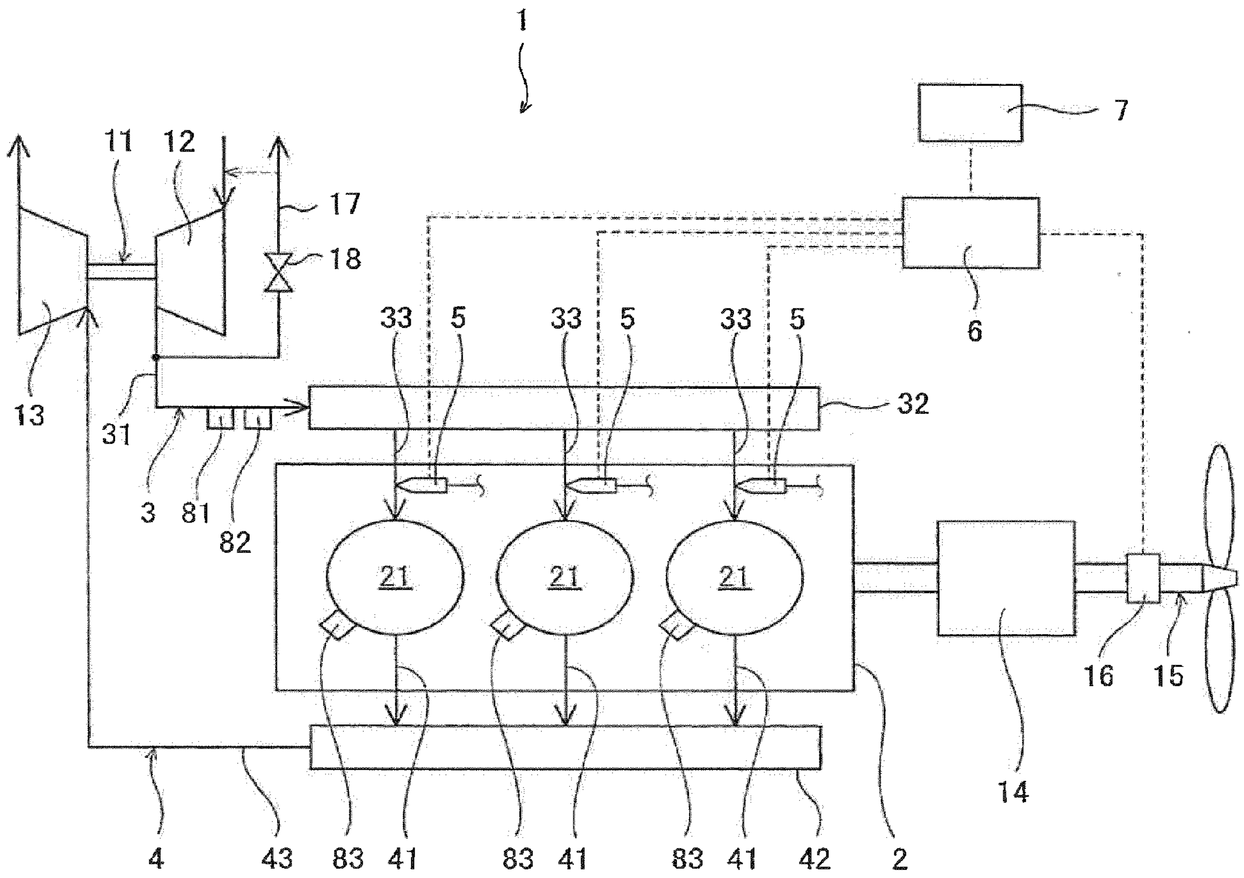
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FIG. 1

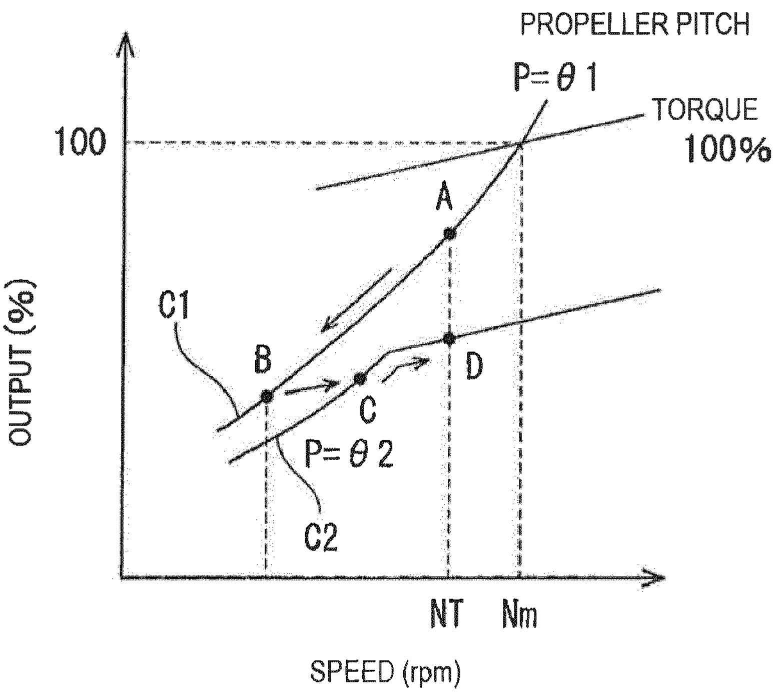
PROPELLER PITCH
P=θ1
TORQUE
100%
100
A
C1
B
C
D
P=θ2
C2
NT
Nm
OUTPUT (%)
SPEED (rpm)

FIG. 2

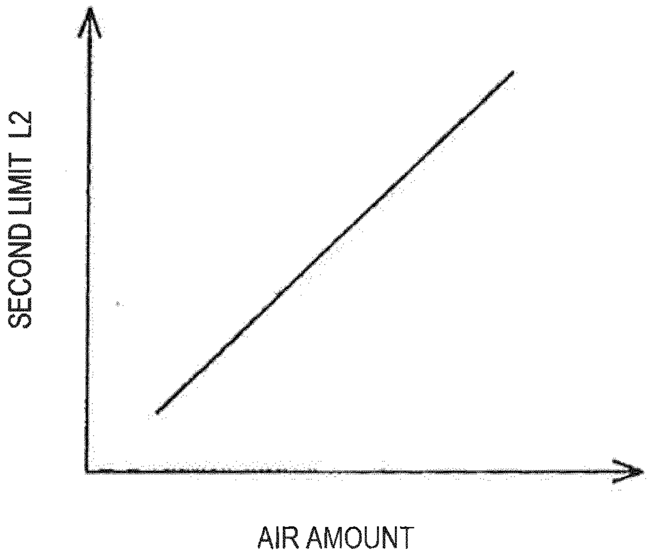
SECOND LIMIT L2
AIR AMOUNT

FIG. 3

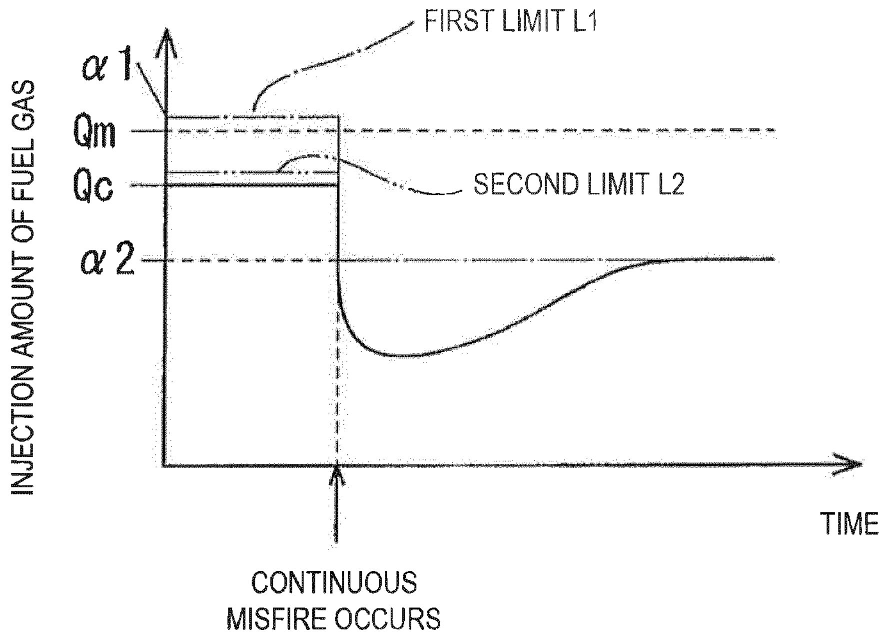
FIRST LIMIT L1
α1
Qm
Qc
SECOND LIMIT L2
α2
INJECTION AMOUNT OF FUEL GAS
TIME
CONTINUOUS
MISFIRE OCCURS

FIG. 4

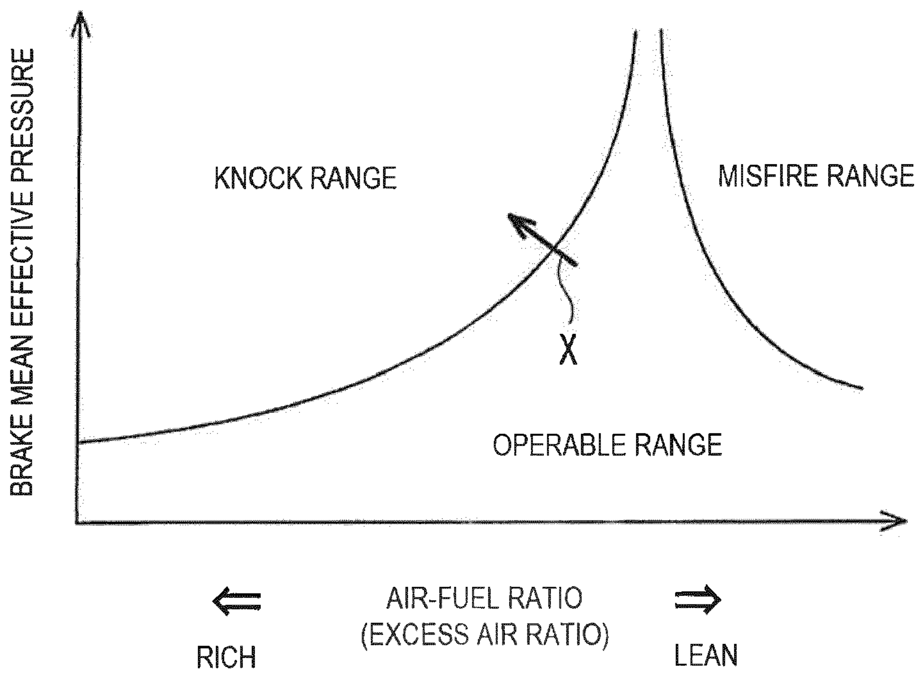
BRAKE MEAN EFFECTIVE PRESSURE
KNOCK RANGE
MISFIRE RANGE
X
OPERABLE RANGE
⇐
RICH
AIR-FUEL RATIO
(EXCESS AIR RATIO)
⇒
LEAN

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 4927

DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2003/188714 A1 (YAMAMOTO TAKAYUKI [JP] ET AL) 9 October 2003 (2003-10-09) * paragraph [0204] - paragraph [0205] * -----	1-5	

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B63H
F02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 March 2017	Martínez Hurtado, L

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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15-03-2017

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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