



[DESCRIPTION]

[TITLE OF INVENTION]

GASEOUS-FUEL ANALYZER AND SYSTEM FOR CONTROLLING GAS
TURBINE

[Technical Field]



G00002

[0001]

The present invention relates to a gaseous-fuel analyzer and a system for controlling a gas turbine.

Priority is claimed on Japanese Patent Application No. 2011-090996, filed April 15, 2011, the content of which is incorporated herein by reference.

[Background Art]

[0002]

In recent years, as a pre-mixed gas of a fuel gas and air is combusted in a lean state, a gas turbine employing a dry low emission (DLE) combustion system that can reduce a Nox discharge amount is used. Since a gas turbine employing the above-mentioned DLE combustion system (also referred to as a premixing combustion system) requires extremely precise measurement of fuel properties and extremely precise combustion control based on measurement values thereof to avoid generation of combustion instability, accidental fire, or the like, in a combustor.

[0003]

In the related art, a lower heating value (LHV) of a fuel gas and a specific gravity (SG) of the fuel gas with respect to the air are measured as fuel properties with high precision using a gas chromatograph, and the flow rate of the fuel gas is controlled based on a Wobbe index (WI) calculated from these measurement values (see Patent Document 1). In addition, the Wobbe index WI can be obtained by dividing the lower heating value LHV by the square root of the specific gravity SG.

[Citation List]

[Patent Document]

[0004]

[Patent Document 1] Japanese Patent Application, First Publication No. 2008-291845

[Summary of Invention]

[Technical Problems]

[0005]

As is well known, the gas chromatograph weighs the respective ingredients in a state in which the respective ingredients contained in the measurement gas are decomposed through a column. In a measurement theory, a time of about 5 to 10 minutes from the sampling of the measurement gas to the output of the measurement values is needed for measurement using the gas chromatograph. Accordingly, each of the measurement values obtained during the period of 5 to 10 minutes from the starting of the gas chromatograph has substantially high precision. However, when properties of the measurement gas, i.e., the fuel gas, are varied, the measurement values cannot trace the property change, and an error occurs due to a time delay (a response delay). As a result, combustion control with high precision becomes difficult.

[0006]

In order to compensate for disadvantages of the above-mentioned gas chromatograph, there is a method of using the fact that SG-LHV characteristics of hydrocarbon contained in the fuel gas (for example, natural gas) can be represented as a linear function. The method may be a method of measuring the density (the specific gravity SG) of the fuel gas using a density gauge, and estimating the lower heating value LHV from the measurement value and the previously obtained SG-LHV characteristics.

In the method, even when the mixing ratio of the hydrocarbon is varied, a relation between the SG and the LHV merely moves according to the

linear function. For this reason, when natural gas obtained by evaporation of LNG having a relatively stable property is used, the method can be applied. However, when a large amount of an inert ingredient such as CO₂, N₂, or the like, is contained as in natural gas directly drawn from a gas field, the relation between the SG and the LHV deviates from the linear function. As a result, estimation of the LHV becomes difficult.

[0007]

As another method, a method of sampling and combusting a portion of the fuel gas using a combustion type calorimeter to measure the calorie (LHV) is considered. However, even when the method is used, the analyzer is complicated and the cost thereof is increased.

[0008]

In consideration of the above-mentioned circumstances, the present invention provides the following two aspects.

(1) Measurement of gaseous fuel properties can be realized with high precision while suppressing an increase in cost.

(2) Combustion control of the gas turbine can be realized with high precision.

[Solution to Problem]

[0009]

According to a first aspect of the present invention, a gaseous-fuel analyzer configured to measure properties of a gaseous fuel, includes: a gas chromatograph configured to measure a calorific value, a specific gravity and a specific ingredient concentration of the gaseous fuel, and output respective measurement values in a certain period; a concentration meter configured to measure the specific ingredient concentration of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph; and a compensation calculation device configured to compensate the measurement values of the calorific value and the specific

gravity simultaneously obtained from the gas chromatograph based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter.

[0010]

In addition, according to a second aspect of the present invention, a gaseous-fuel analyzer configured to measure properties of a gaseous fuel, includes: a gas chromatograph configured to measure a calorific value and a specific ingredient concentration of the gaseous fuel and output respective measurement values in a certain period; a concentration meter configured to measure the specific ingredient concentration of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph; a specific gravity meter configured to measure a specific gravity of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph; and a compensation calculation device configured to compensate the measurement values of the calorific value simultaneously obtained from the gas chromatograph and the specific gravity obtained from the specific gravity meter based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter.

[0011]

Further, according to a third aspect of the present invention, in the first or second aspect, the compensation calculation device may compensate the measurement values of the calorific value and the specific gravity based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter, and a correlation between the calorific value and the specific ingredient

concentration and a correlation between the specific gravity and the specific ingredient concentration, which are previously obtained using the gas chromatograph.

[0012]

Furthermore, according to a fourth aspect of the present invention, in the third aspect, the compensation calculation device may calculate a calorific value compensation coefficient and a specific gravity compensation coefficient by substituting the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the concentration meter into an arithmetic expression of the calorific value compensation coefficient and the specific gravity compensation coefficient drafted based on an approximation function representing the correlation between the calorific value and the specific ingredient concentration and an approximation function representing the correlation between the specific gravity and the specific ingredient concentration and using the specific ingredient concentration obtained from the gas chromatograph and the concentration meter as a parameter.

[0013]

Further, according to a fifth aspect of the present invention, a system for controlling a gas turbine includes: a gas turbine; a fuel supply line connected to a combustor of the gas turbine; a fuel flow rate control valve inserted into the fuel supply line; the gaseous-fuel analyzer according to any of the first to fourth aspects configured to measure properties of a gaseous fuel flowing through the fuel supply line; and a control device configured to calculate a Wobbe index based on measurement values of a calorific value and a specific gravity of the gaseous fuel obtained from the gaseous-fuel analyzer, and control a degree of an aperture of the fuel flow rate control valve based on the Wobbe index.

[Advantageous Effects of Invention]

[0014]

According to the gaseous-fuel analyzer according to the present invention, based on the measurement value of the specific ingredient concentration of the gaseous fuel obtained from the gas chromatograph and the measurement value of the specific ingredient concentration of the gaseous fuel simultaneously obtained from the concentration meter, the calorific value of the gaseous fuel and the measurement value of the specific gravity, which are simultaneously obtained from the gas chromatograph, are compensated. For this reason, the highly precise measurement values of the calorific value and the specific gravity can be obtained while suppressing the error due to the time delay. As the concentration meter, for example, a relatively inexpensive instrument such as an infrared light analyzer can be used. That is, according to the gaseous-fuel analyzer, measurement of the gaseous fuel properties can be realized with high precision while suppressing an increase in cost.

[0015]

In addition, according to the system for controlling a gas turbine according to the present invention, the Wobbe index is calculated based on the highly precise measurement values of the calorific value and the specific gravity obtained from the above-mentioned gaseous-fuel analyzer, and the degree of the aperture of the fuel flow rate control valve is controlled based on the Wobbe index. Accordingly, combustion control of the gas turbine can be realized with high precision.

[Brief Description of Drawings]

[0016]

FIG. 1 is a block diagram of a system for controlling a gas turbine according to a first embodiment;

FIG. 2A is a first explanation view related to a measurement theory of fuel gas properties according to the embodiment;

FIG. 2B is the first explanation view related to the measurement theory of the fuel gas properties according to the embodiment;

FIG. 3A is a second explanation view related to a measurement theory of fuel gas properties according to the embodiment;

FIG. 3B is the second explanation view related to the measurement theory of the fuel gas properties according to the embodiment;

FIG. 4 is a block diagram of a system for controlling a gas turbine according to a second embodiment; and

FIG. 5 is an explanation view related to a variant of the embodiment.
[Description of Embodiments]

[0017]

Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

(First embodiment)

First, a first embodiment of the present invention will be described. FIG. 1 is a block diagram showing a schematic configuration of a system for controlling a gas turbine A according to the first embodiment. As shown in FIG. 1, the system for controlling the gas turbine A is constituted by a gas turbine 1, a fuel supply line 2, a fuel flow rate control valve 3, a sampling device 4, a gaseous-fuel analyzer 5, and a gas turbine control device 6. In addition, FIG. 1, a solid arrow represents a fuel gas, and a dotted arrow represents an electrical signal.

[0018]

For example, the gas turbine 1 is a gas turbine employing a DLE combustion system (a premixing combustion system) that can reduce the Nox discharge amount by combusting a pre-mixed gas of a fuel gas and air in a lean state. The fuel supply line 2 is a pipe line connected to a combustor (not shown) of the gas turbine 1 and configured to supply a fuel gas. The fuel gas such as natural gas or the like is supplied into the combustor of the

gas turbine 1 via the fuel supply line 2. In addition, while not shown in FIG. 1, an air supply line configured to supply compressed air is also connected to the combustor of the gas turbine 1.

[0019]

The fuel flow rate control valve 3 is an automatic control valve installed at the fuel supply line 2, and a degree of an aperture thereof is controlled according to a fuel flow rate control signal FC input from the gas turbine control device 6. That is, a flow rate of the fuel gas supplied into the gas turbine 1 is controlled by the aperture control of the fuel flow rate control valve 3. The sampling device 4 is installed in the fuel supply line 2 at an upstream side of the fuel flow rate control valve 3, and a portion of the fuel gas flowing through the fuel supply line 2 is divided (sampled) to be introduced into the gaseous-fuel analyzer 5.

[0020]

The gaseous-fuel analyzer 5 measures properties of the fuel gas introduced from the fuel supply line 2 via the sampling device 4. The gaseous-fuel analyzer 5 is constituted by a gas chromatograph 5a, an infrared light analyzer 5b, and a compensation calculation device 5c. The fuel gas introduced into the gaseous-fuel analyzer 5 is divided into the gas chromatograph 5a and the infrared light analyzer 5b.

[0021]

The gas chromatograph 5a measures a lower heating value LHV of the fuel gas, a specific gravity SG with respect to the air and a concentration of carbon dioxide (CO₂), and outputs the respective measurement values LHV_gc, SG_gc and CO2_gc to the compensation calculation device 5c in a certain period. As described above, the gas chromatograph 5a weighs the respective ingredients in a state in which the respective ingredients contained in the measurement gas (the fuel gas) are separated through a column. In a measurement theory, in the gas chromatograph 5a, while the measurement

values are measured with high precision, a time of 5 to 10 minutes from sampling of the fuel gas to the output of the measurement values is needed. That is, the gas chromatograph 5a outputs the respective measurement values LHV_gc, SG_gc and CO2_gc in a period of 5 to 10 minutes.

[0022]

The infrared light analyzer 5b is a gas analyzer using a non-dispersive infrared absorption method (an ND-IR method), which measures a concentration of the carbon dioxide (CO₂) of the fuel gas and outputs the measurement value CO2_ir to the compensation calculation device 5c in a period shorter than that of the gas chromatograph 5a. In the measurement theory, the infrared light analyzer 5b is less precise than the gas chromatograph 5a. However, in the infrared light analyzer 5b, the measurement value CO2_ir can be output at an extremely short period (an order of several seconds), which can be regarded as being substantially continuous in comparison with the gas chromatograph 5a.

[0023]

The compensation calculation device 5c is a microcomputer, in which, for example, a memory, a central processing unit (CPU) core, an input/output interface, and so on, are integrally combined. The compensation calculation device 5c compensates the measurement values LHV_gc and SG_gc of the lower heating value LHV and the specific gravity SG simultaneously obtained from the gas chromatograph 5a based on the measurement value CO2_gc of the CO₂ concentration obtained from the gas chromatograph 5a and the measurement value CO2_ir of the CO₂ concentration simultaneously obtained from the infrared light analyzer 5b. In addition, the compensation calculation device 5c outputs the measurement values LHV_c and SG_c to the gas turbine control device 6 after the compensation.

[0024]

The gas turbine control device 6 calculates the Wobbe index WI based

on the measurement values LHV_c and SG_c of the lower heating value LHV and the specific gravity SG of the fuel gas obtained from the gaseous-fuel analyzer 5 (the compensation calculation device 5c). The gas turbine control device 6 outputs the fuel flow rate control signal FC for controlling the degree of the aperture of the fuel flow rate control valve 3 (controlling the fuel gas flow rate) based on the calculated Wobbe index WI to the fuel flow rate control valve 3. In addition, the gas turbine control device 6 outputs an air flow rate control signal AC for controlling a degree of an aperture (controlling an air flow rate) of an air flow rate control valve (not shown) inserted into an air supply line of the gas turbine 1 to an air flow rate control valve.

[0025]

Next, an operation of the above-mentioned system for controlling the gas turbine A will be described in detail. That is, a measurement operation of the fuel gas properties by the gaseous-fuel analyzer 5 and combustion control operation (fuel flow rate control) of the gas turbine 1 by the gas turbine control device 6 will be described in detail.

[0026]

<Measurement theory of fuel gas properties>

First, for the purpose of easy understanding of the measurement operation of the fuel gas properties by the gaseous-fuel analyzer 5, the measurement theory of the fuel gas properties of the embodiment will be described.

As shown in FIG. 2A, the gas chromatograph 5a outputs the measurement values LHV_{gc} and SG_{gc} of the fuel gas properties (the lower heating value LHV, the specific gravity SG, and so on) in the period of 5 to 10 minutes. The respective measurement values obtained from the above-mentioned gas chromatograph 5a in the period of 5 to 10 minutes have substantially high precision (extremely near an actual value). However, when the fuel gas properties are varied in the short term, the measurement

values cannot trace the property change, and an error due to a time delay (a response delay) by a maximum of two steps (two periods) occurs.

[0027]

The inventors of the application have verified property data during a certain period measured using the gas chromatograph of natural gas produced from a certain area. As a result, it has been found that, when the concentration of, in particular, the carbon dioxide (CO_2) of the inert ingredients contained in the natural gas is large and the variation in concentration is large, the lower heating value LHV and the specific gravity SG required for calculation of the Wobbe index WI are largely varied.

[0028]

The inventors of the application have investigated a relation between the CO_2 concentration and the lower heating value LHV and a relation between the CO_2 concentration and the specific gravity SG using the property data of the natural gas for the certain period. As a result, as shown in FIG. 3A, it has been found that the CO_2 concentration and the lower heating value LHV have a clear correlation, and as shown in FIG. 3B, it has been found that the CO_2 concentration and the specific gravity SG have a certain measure of correlation, although not to the extent of the lower heating value LHV.

[0029]

As shown in FIG. 3A, the correlation between the CO_2 concentration and the lower heating value LHV can be approximate to an exponential function with high precision (all of the data is within a range of $\pm 1\%$ from an approximation function curve). This means that, when the correlation between the CO_2 concentration and the lower heating value LHV is previously obtained, the lower heating value LHV can be estimated from the CO_2 concentration measurement value of the fuel gas. Hereinafter, an approximation function (an exponential function) representing the correlation between the CO_2 concentration and the lower heating value LHV is defined as

the following Equation (1). In addition, in the following Equation (1), A and B are constants, and e is a base of a natural logarithm.

[0030]

$$LHV_gc = A \times e^{(B \times CO2_gc)} \quad \dots(1)$$

[0031]

In addition, as shown in FIG. 3B, the correlation between the CO₂ concentration and the specific gravity SG is slightly lower than the correlation between the CO₂ concentration and the lower heating value LHV, and there seem to be two substantially parallel data categories. However, the one of the data categories that has relatively high correlation can more precisely approximate the exponential function than the other data category. This means that, when the correlation between the CO₂ concentration and the specific gravity SG is previously obtained, the specific gravity SG can be estimated from the CO₂ concentration measurement value of the fuel gas. Hereinafter, an approximation function (an exponential function) representing the correlation between the CO₂ concentration and the specific gravity SG is defined as the following Equation (2). In addition, in the following Equation (2), C and D are constants, and e is a base of a natural logarithm.

[0032]

$$SG_gc = C \times e^{(D \times CO2_gc)} \quad \dots(2)$$

[0033]

Next, while a measurement unit of the CO₂ concentration is a problem, the measurement value CO₂_gc of the CO₂ concentration obtained from the gas chromatograph 5a includes an error caused by the time delay of a maximum of two steps like the other measurement values LHV_gc and SG_gc. On the other hand, the infrared light analyzer 5b is less precise than the gas chromatograph 5a. However, the infrared light analyzer 5b outputs the

measurement value CO2_ir of the CO₂ concentration in the extremely short period, which can be regarded as being substantially continuous in comparison with the gas chromatograph 5a. For this reason, an error caused by the time delay is negligible (see FIG. 2B).

[0034]

That is, the measurement value CO2_gc of the CO₂ concentration obtained from the gas chromatograph 5a is not a current value but a value from a maximum of two steps prior. However, the measurement value CO2_ir of the CO₂ concentration obtained from the infrared light analyzer 5b can be regarded as the current value. For this reason, as the compensation is performed such that a difference between the simultaneously obtained CO2_gc and CO2_ir is removed (in other words, such that the CO2_gc coincides with the CO2_ir), the measurement values of the lower heating value LHV and the specific gravity SG can be obtained with high precision while suppressing the error caused by the time delay.

[0035]

Specifically, a calorific value compensation coefficient Z_LHV_co2 configured to compensate for the time delay error included in the measurement value LHV_gc of the lower heating value LHV obtained from the gas chromatograph 5a can be calculated by the following Equation (3) derived based on the measurement values CO2_gc and CO2_ir of the CO₂ concentration simultaneously obtained from the gas chromatograph 5a and the infrared light analyzer 5b and Equation (1).

[0036]

$$Z_LHV_co2 = \frac{A \times e^{(B \times CO2_ir)}}{A \times e^{(B \times CO2_gc)}} = e^{[B \times (CO2_ir - CO2_gc)]} \quad \dots(3)$$

[0037]

In addition, a specific gravity compensation coefficient Z_SG_co2 configured to compensate for the time delay error included in the

measurement value SG_{gc} of the specific gravity SG obtained from the gas chromatograph 5a can be calculated by the following Equation (4) derived based on the measurement values CO₂_{gc} and CO₂_{ir} of the CO₂ concentration simultaneously obtained from the gas chromatograph 5a and the infrared light analyzer 5b and Equation (2).

[0038]

$$Z_SG_co2 = \frac{C \times e^{(D \times CO2_ir)}}{C \times e^{(D \times CO2_gc)}} = e^{[D \times (CO2_ir - CO2_gc)]} \quad \dots(4)$$

[0039]

Accordingly, finally, the measurement values of the lower heating value LHV and the specific gravity SG that do not include the error caused by the time delay (the measurement values LHV_c and SG_c after compensation) are expressed by the following Equations (5) and (6).

[0040]

$$LHV_c = LHV_gc \times Z_LHV_co2 \quad \dots(5)$$

$$SG_c = SG_gc \times Z_SG_co2 \quad \dots(6)$$

[0041]

As described above, a correlation between the CO₂ concentration and the lower heating value LHV and a correlation between the CO₂ concentration and the specific gravity SG of the fuel gas are previously obtained using the gas chromatograph, and an arithmetic expression of the calorific value compensation coefficient Z_{LHV_co2} and the specific gravity compensation coefficient Z_{SG_co2} is drafted based on the approximation function representing these correlations. Then, the measurement values CO₂_{gc} and CO₂_{ir} of the CO₂ concentration simultaneously obtained from the gas chromatograph 5a and the infrared light analyzer 5b are substituted into the arithmetic expression. Accordingly, the time delay error included in the measurement value LHV_{gc} of the lower heating value LHV and the

measurement value SG_{gc} of the specific gravity SG simultaneously obtained from the gas chromatograph 5a can be compensated.

[0042]

In addition, in calculation of the inventor(s) of the application, the Wobbe index $WI (= LHV_{gc}/\sqrt{SG_{gc}})$ calculated using the measurement value LHV_{gc} and the measurement value SG_{gc} before the compensation has an error larger than 1% caused by the time delay. However, it has been confirmed that an error caused by the time delay in the Wobbe index $WI (=LHV_c/\sqrt{SG_c})$ which is calculated using the measurement value LHV_c and the measurement value SG_c after the compensation is suppressed to 0.6% or less.

[0043]

That is, according to the measurement theory of the fuel gas properties of the embodiment, disadvantages of the gas chromatograph 5a (although it is high precision, when the fuel gas properties are varied in the short term, the error caused by the time delay occurs) can be largely overcome.

Accordingly, the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG can be obtained with high precision (near the current value) while suppressing the time delay error.

[0044]

<Measurement operation of fuel gas properties by gaseous-fuel analyzer 5>

Next, based on the above-mentioned measurement theory of the fuel gas properties, a measurement operation of the fuel gas properties by the gaseous-fuel analyzer 5 of the embodiment will be described.

In addition, in an operation of the gas turbine 1 (in supply of the fuel gas), while the measurement value $CO2_{ir}$ of the CO_2 concentration of the fuel gas is substantially continuously output from the infrared light analyzer 5b (see FIG. 2B), the measurement values LHV_{gc} , SG_{gc} and $CO2_{gc}$ of the

lower heating value LHV, the specific gravity SG and the CO₂ concentration of the fuel gas are output in the period of 5 to 10 minutes from the gas chromatograph 5a, and the measurement values of the previous step are continuously output for 5 to 10 minutes until the measurement values of the current step are determined (see FIGS. 2A and 2B).

[0045]

The compensation calculation device 5c of the gaseous-fuel analyzer 5 samples the measurement values LHV_{gc}, SG_{gc} and CO₂_{gc} of the lower heating value LHV, the specific gravity SG and the CO₂ concentration output from the gas chromatograph 5a, and the measurement value CO₂_{ir} of the CO₂ concentration output from the infrared light analyzer 5b in a certain sampling period. The sampling period is set to be smaller than the measurement period (5 to 10 minutes) of the gas chromatograph 5a and sufficiently larger than the measurement period (an order of several seconds) of the infrared light analyzer 5b.

[0046]

Accordingly, while the measurement values LHV_{gc}, SG_{gc} and CO₂_{gc} obtained (sampled) from the gas chromatograph 5a by the compensation calculation device 5c at every sampling timing are values of a maximum of two steps prior, the measurement value CO₂_{ir} obtained from the infrared light analyzer 5b can be regarded as the current value.

[0047]

The compensation calculation device 5c previously stores Equations (3) and (4) in the internal memory. The compensation calculation device 5c calculates the calorific value compensation coefficient Z_{LHV_co2} and the specific gravity compensation coefficient Z_{SG_co2} by substituting the measurement value CO₂_{gc} and CO₂_{ir} of the CO₂ concentration among the respective simultaneously sampled measurement values for Equations (3) and (4).

[0048]

In addition, the compensation calculation device 5c previously stores Equations (5) and (6) in the internal memory. The compensation calculation device 5c calculates the measurement value LHV_c , in which the time delay error is compensated, by multiplying the calorific value compensation coefficient Z_LHV_co2 by the measurement value LHV_gc of the lower heating value LHV among the simultaneously sampled measurement values based on Equation (5). In addition, the compensation calculation device 5c calculates the measurement value SG_c , in which the time delay error is compensated, by multiplying the specific gravity compensation coefficient Z_SG_co2 by the measurement value SG_gc of the specific gravity SG based on Equation (6).

[0049]

The compensation calculation device 5c outputs the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG, which are obtained by the processing, in which the time delay error is compensated, and which are extremely close to the current value (the actual value) with high precision, to the gas turbine control device 6. In this way, the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG are output from the compensation calculation device 5c to the gas turbine control device 6 in a certain sampling period with high precision.

[0050]

<Combustion control operation of gas turbine 1 by gas turbine control device 6>

Next, a combustion control operation (fuel flow rate control) of the gas turbine 1 by the gas turbine control device 6 will be described.

In addition, as described above, the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific

gravity SG are input into the gas turbine control device 6 from the gaseous-fuel analyzer 5 (the compensation calculation device 5c) at a certain period with high precision.

[0051]

In general, a heat input H (MJ/hr) into the combustor of the gas turbine 1 is represented as the following Equation (7) using the lower heating value LHV (MJ/Nm³) and a fuel flow rate Qf (Nm³/h).

[0052]

$$H = LHV \times Qf \quad \dots(7)$$

[0053]

In addition, the fuel flow rate Qf is expressed as the following Equation (8) with respect to an orifice (corresponding to a flow meter, the fuel flow rate control valve 3, and a fuel nozzle). Further, in the following Equation (8), C is a flow rate coefficient, A is an orifice area (m²), ΔP is an orifice-front/rear pressure difference (Pa), pf is a fuel density (kg/m³), pan is an air density (kg/Nm³) in a standard state, SG is a fuel specific gravity (air=1.0), Tn is a temperature (K) in a standard state, Tf is a fuel gas temperature (K), Pn is a pressure (Pa) in a standard state, and Pf is a fuel gas pressure (Pa).

[0054]

$$Qf = CA \sqrt{\frac{2\Delta P}{\rho f}} = CA \sqrt{\frac{2\Delta P}{SG \times \rho an \times Tn / Tf \times Pf / Pn}} \quad \dots(8)$$

[0055]

Accordingly, the measurement values of the flow rate coefficient C, the orifice area A, the orifice-front/rear pressure difference ΔP, the fuel gas temperature Tf and the fuel gas pressure Pf are obtained, and further, as the Wobbe index Wl is known from the following Equation (9), the heat input H into the combustor of the gas turbine 1 is determined. Alternatively, when

the heat input, which is a target, is determined, and the flow rate coefficient of the fuel flow rate control valve 3 and the aperture characteristics of the orifice area are known, the degree of the aperture of the fuel flow rate control valve 3 can be determined.

[0056]

$$H \propto \frac{LHV}{\sqrt{SG}} = \text{Wobbe Index} \quad \dots(9)$$

[0057]

That is, the gas turbine control device 6 calculates the Wobbe index WI from the following Equation (9) using the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG obtained from the gaseous-fuel analyzer 5 in a certain period. In addition, the gas turbine control device 6 determines the degree of the aperture of the fuel flow rate control valve 3 from the Wobbe index WI based on the control theory, and controls the fuel flow rate control valve 3 to become the degree of the determined aperture, i.e., the determined fuel gas flow rate (outputs the fuel flow rate control signal FC). Furthermore, at this time, the gas turbine control device 6 controls an air flow rate control valve (not shown) (outputs the air flow rate control signal AC) such that the flow rate of the air supplied into the combustor of the gas turbine 1.

[0058]

As described above, according to the embodiment, the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG can be obtained from the gaseous-fuel analyzer 5 with high precision while suppressing the time delay error. The infrared light analyzer 5b used for compensation of the time delay error is a relatively inexpensive instrument. Accordingly, according to the embodiment, the gaseous fuel properties can be measured with high precision while an increase in cost is suppressed.

In addition, according to the embodiment, since the Wobbe index WI is calculated based on the measurement value LHV_c of the lower heating value LHV and the measurement value SG_c of the specific gravity SG obtained from the above-mentioned gaseous-fuel analyzer 5 with high precision and the aperture of the fuel flow rate control valve 3 is controlled based on the Wobbe index WI (the fuel flow rate is controlled), combustion control of the gas turbine 1 can be realized with high precision.

[0059]

(Second embodiment)

Next, a second embodiment of the present invention will be described.

While the specific gravity SG is decreased in a conventional case when the CO₂ concentration of the fuel gas is reduced, the specific gravity SG may be increased when concentration of another ingredient such as C₂ or C₃ is rapidly increased. When the property change of the above-mentioned fuel gas occurs, the measurement value SG_c after the compensation may have an error larger than that of the measurement value SG_{gc} before the compensation. The second embodiment can also correspond to the property change of the above-mentioned fuel gas.

[0060]

FIG. 4 is a block diagram showing a schematic configuration of a system for controlling a gas turbine B according to the second embodiment. As shown in FIG. 4, the system for controlling the gas turbine B is distinguished from the system for controlling the gas turbine A of the first embodiment in that a gaseous-fuel analyzer 5' to which a specific gravity meter 5d is newly added is provided.

In the system for controlling the gas turbine B, since components other than the gaseous-fuel analyzer 5' are the same as in the first embodiment, a description thereof will not be repeated here.

[0061]

The fuel gas introduced into the gaseous-fuel analyzer 5' via the sampling device 4 is divided into the gas chromatograph 5a, the infrared light analyzer 5b and the specific gravity meter 5d. The specific gravity meter 5d measures the specific gravity SG of the fuel gas, and outputs the measurement value SG_gc to the compensation calculation device 5c in a period shorter than that of the gas chromatograph 5a.

The specific gravity meter 5d is less precise than the gas chromatograph 5a like the infrared light analyzer 5b. However, the measurement value SG_gc can be output to the specific gravity meter 5d at an extremely short period, which can be regarded as being substantially continuous in comparison with the gas chromatograph 5a.

In addition, only the measurement values LHV_gc and CO2_gc of the lower heating value LHV and the CO₂ concentration of the fuel gas are output from the gas chromatograph 5a.

[0062]

The compensation calculation device 5c samples the measurement values LHV_gc and CO2_gc of the lower heating value LHV and the CO₂ concentration output from the gas chromatograph 5a, the measurement value CO2_ir of the CO₂ concentration output from the infrared light analyzer 5b, and the measurement value SG_gc of the specific gravity SG output from the specific gravity meter 5d at a certain sampling period.

[0063]

While the measurement values LHV_gc and CO2_gc obtained (sampled) from the gas chromatograph 5a by the compensation calculation device 5c at every sampling timing are values of a maximum of two steps prior, the measurement value CO2_ir obtained from the infrared light analyzer 5b and the measurement value SG_gc obtained from the specific gravity meter 5d can be regarded as current values.

[0064]

Similarly to the first embodiment, the compensation calculation device 5c calculates the calorific value compensation coefficient Z_{LHV_co2} and the specific gravity compensation coefficient Z_{SG_co2} by substituting the measurement value $CO2_gc$ and $CO2_ir$ of the CO_2 concentration among the respective measurement values, which are simultaneously sampled as described above, for Equations (3) and (4).

[0065]

Similarly to the first embodiment, the compensation calculation device 5c calculates the measurement value LHV_c , in which the time delay error is compensated, by multiplying the calorific value compensation coefficient Z_{LHV_co2} by the measurement value LHV_gc of the lower heating value LHV among the respective measurement values, which are simultaneously sampled, based on Equation (5). In addition, the compensation calculation device 5c calculates the measurement value SG_c , in which the time delay error is compensated, by multiplying the specific gravity compensation coefficient Z_{SG_co2} by the measurement value SG_gc of the specific gravity SG based on Equation (6).

[0066]

In the second embodiment, the measurement value SG_gc of the specific gravity SG substituted for Equation (6) is a value approximate to the current value obtained from the specific gravity meter 5d with no time delay error. For this reason, even when a property change of the fuel gas, in which the specific gravity SG , which is conventionally decreased, is increased, occurs, the measurement value SG_c after the compensation can suppress an error to be smaller than that of the measurement value SG_gc before the compensation.

[0067]

Hereinabove, while the first and second embodiments of the present invention have been described, the present invention is not limited to these

embodiments but the following variants may be provided.

(1) In the first and second embodiments, the case in which the lower heating value LHV is measured as the calorific value needed for calculation of the Wobbe index WI has been described. However, instead of the lower heating value LHV, a higher heating value HHV may be calculated and the Wobbe index WI may be calculated from the higher heating value HHV and the specific gravity SG.

[0068]

(2) In the first and second embodiments, the case in which an infrared light analyzer 5d is used as the concentration meter configured to measure the specific ingredient concentration (the CO₂ concentration) of the fuel gas has been described. However, any concentration meter may be used as long as the concentration meter can output the measurement value at a period shorter than that of the gas chromatograph 5a, which can be regarded as being continuous. In addition, there is no specific need to measure the CO₂ concentration as the specific ingredient concentration of the fuel gas, and the concentration of an ingredient that largely exerts an influence on a variation of the lower heating value LHV and the specific gravity SG among the ingredients contained in the fuel gas may be measured.

[0069]

(3) In the first and second embodiments, while the case in which a correlation between the CO₂ concentration and the lower heating value LHV and a correlation between the CO₂ concentration and the specific gravity SG of the fuel gas are approximate to an exponential function has been described, these correlations may be approximate by another function. In addition, table data representing these correlations is prepared (stored in an internal memory of the compensation calculation device 5c), and the table data may be used instead of the approximation function.

[0070]

(4) In the first and second embodiments, there is a case in which a drift of the infrared light analyzer 5d is assumed (a case in which an error of the measurement value $CO2_{ir}$ of the CO_2 concentration with respect to the actual value is large). In this case, as shown in FIG. 5, the measurement value $CO2_{ir}$ of the CO_2 concentration sampled from the infrared light analyzer 5d at the same sampling timing as the gas chromatograph 5a is held, and after several samplings, a difference between the measurement value $CO2_{ir}$ of the CO_2 concentration sampled from the infrared light analyzer 5d and the held measurement value $CO2_{ir}$ may be used to calculate the Z_{LHV_co2} and the specific gravity compensation coefficient Z_{SG_co2} .

[0071]

According to the gaseous-fuel analyzer according to the aspect of the present invention, the measurement values of the calorific value and the specific gravity can be obtained with high precision while suppressing the error caused by the time delay. In addition, for example, a relatively inexpensive instrument such as an infrared light analyzer can be used as the concentration meter. That is, measurement of the gaseous fuel properties can be realized with high precision while suppressing an increase in cost.

[Reference Signs List]

[0072]

A, B...system for controlling a gas turbine, 1...gas turbine, 2...fuel supply line, 3...fuel flow rate control valve, 4...sampling device, 5, 5'...gaseous-fuel analyzer, 6...gas turbine control device, 5a...gas chromatograph, 5b...infrared light analyzer, 5c...compensation calculation device, 5d...specific gravity meter

[CLAIMS]

[Claim 1]

A gaseous-fuel analyzer configured to measure properties of a gaseous fuel, the gaseous-fuel analyzer comprising:

a gas chromatograph configured to measure a calorific value, a specific gravity and a specific ingredient concentration of the gaseous fuel, and output respective measurement values in a certain period;

a concentration meter configured to measure the specific ingredient concentration of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph; and

a compensation calculation device configured to compensate the measurement values of the calorific value and the specific gravity simultaneously obtained from the gas chromatograph based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter.

[Claim 2]

A gaseous-fuel analyzer configured to measure properties of a gaseous fuel, the gaseous-fuel analyzer comprising:

a gas chromatograph configured to measure a calorific value and a specific ingredient concentration of the gaseous fuel and output respective measurement values in a certain period;

a concentration meter configured to measure the specific ingredient concentration of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph;

a specific gravity meter configured to measure a specific gravity of the gaseous fuel and output the measurement values in a period shorter than that of the gas chromatograph; and

a compensation calculation device configured to compensate the

measurement values of the calorific value simultaneously obtained from the gas chromatograph and the specific gravity obtained from the specific gravity meter based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter.

[Claim 3]

The gaseous-fuel analyzer according to claim 1 or 2, wherein the compensation calculation device compensates the measurement values of the calorific value and the specific gravity based on the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the measurement value of the specific ingredient concentration simultaneously obtained from the concentration meter, and a correlation between the calorific value and the specific ingredient concentration and a correlation between the specific gravity and the specific ingredient concentration, which are previously obtained using the gas chromatograph.

[Claim 4]

The gaseous-fuel analyzer according to claim 3, wherein the compensation calculation device calculates a calorific value compensation coefficient and a specific gravity compensation coefficient by substituting the measurement value of the specific ingredient concentration obtained from the gas chromatograph and the concentration meter into an arithmetic expression of the calorific value compensation coefficient and the specific gravity compensation coefficient drafted based on an approximation function representing the correlation between the calorific value and the specific ingredient concentration and an approximation function representing the correlation between the specific gravity and the specific ingredient concentration and using the specific ingredient concentration obtained from the gas chromatograph and the concentration meter as a parameter.

[Claim 5]

A system for controlling a gas turbine comprising:

- a gas turbine;
- a fuel supply line connected to a combustor of the gas turbine;
- a fuel flow rate control valve inserted into the fuel supply line;
- the gaseous-fuel analyzer of any one of claims 1 to 4 configured to measure properties of a gaseous fuel flowing through the fuel supply line; and
- a control device configured to calculate a Wobbe index based on measurement values of a calorific value and a specific gravity of the gaseous fuel obtained from the gaseous-fuel analyzer, and control a degree of an aperture of the fuel flow rate control valve based on the Wobbe index.