

PAINT DRYING CONTROL APPARATUS, PAINT DRYING CONTROL
METHOD, AND PAINT DRYING CONTROL SYSTEM

BACKGROUND

Technical Field

[0001]

The present invention relates to a paint drying control apparatus, a paint drying control method, and a paint drying control system.

Related Art

[0002]

The utilization of green fuels is being promoted toward the realization of a decarbonized society. As the major green fuel, hydrogen and ammonia are attracting attention. At normal temperature, hydrogen is a gas but ammonia is a liquid, and thus ammonia is easier to transport than hydrogen. Therefore, from the viewpoint of transportation, there is a trend to directly use ammonia as an alternative fuel to city gas.

[0003]

Possible applications using ammonia as a fuel include, for example, power generation, heat treatment, and paint drying. However, it is necessary to check the influence of changing the fuel from city gas to ammonia for each application and take measures as necessary.

[0004]

Regarding paint drying, for example, JP 2024-036169 A

describes "a gas treatment system comprising: a paint drying furnace that dries a painted workpiece; a combustion device that includes a combustion chamber to which a part of exhaust gas discharged from the paint drying furnace is returned, and supplies drying gas generated by combustion treatment in the combustion chamber to the paint drying furnace; a deodorization treatment device that removes an odorous component contained in residual gas in the exhaust gas that has not been returned to the combustion chamber; a denitration treatment device that removes nitrogen oxides contained in the residual gas; and a gas return path that sends deodorization/denitration gas generated from treatment by the deodorization treatment device and the denitration treatment device to either the combustion chamber or the paint drying furnace, or both."

[0005]

Patent document 1 JP 2024-036169 A

SUMMARY

[0006]

In the technique described in JP 2024-036169 A, the influence of using ammonia as the fuel is not considered.

[0007]

When hot air generated by ammonia combustion is applied to paint drying, since ammonia that is not included in the conventional drying step is included in the drying atmosphere, high concentration of ammonia in the drying

atmosphere chemically may inhibit the formation of a coating film and deteriorate the coating film quality. Therefore, it is necessary to take measures against this problem.

[0008]

The present invention has been made in view of the above-described point, and an object thereof is to obtain good coating film quality when hot air generated by ammonia combustion is applied to paint drying.

[0009]

The present application includes a plurality of means for solving at least a part of the above-described problem, but an example thereof can be presented as follows:

[0010]

In order to solve the above-described problem, one aspect of the present invention is a paint drying control apparatus that controls a paint drying apparatus for drying a painted object, the paint drying control apparatus including a storage device and a processing device, in which the storage device stores a paint type coefficient corresponding to a paint type, and the processing device receives an input of a paint type used to paint the object and a drying time of the object that have been input from a user, acquires a temperature of a drying atmosphere for drying the object and an ammonia concentration in the drying atmosphere that have been obtained by burning mixed gas containing at least ammonia gas in a combustion furnace

in the paint drying apparatus, calculates an ammonia concentration threshold of the ammonia gas based on the drying time, the paint type coefficient corresponding to the paint type used to paint the object, and the temperature of the drying atmosphere, generates a control condition related to a change in a flow rate of each gas constituting the mixed gas to the combustion furnace when the acquired ammonia concentration in the drying atmosphere is equal to or higher than the ammonia concentration threshold, and outputs the generated control condition.

[0011]

According to the present invention, it is possible to obtain good coating film quality when hot air generated by ammonia combustion is applied to paint drying.

[0012]

Problems, configurations, and effects other than those described above will be clarified by the following description of an embodiment.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

FIG. 1 is a diagram illustrating a configuration example of a paint drying control system according to an embodiment of the present invention;

FIG. 2 is a diagram illustrating a configuration example of a paint drying control apparatus;

FIG. 3 is a flowchart for describing an example of

paint drying control processing by the paint drying control apparatus; and

FIG. 4 is a diagram illustrating a display example of a user interface (UI) screen.

DETAILED DESCRIPTION

[0014]

Hereinafter, an embodiment of the present invention will be described with reference to the drawings. An embodiment is an example for describing the present invention, and omission and simplification are appropriately made for clarity of the description. The present invention can be implemented in various other forms. Unless otherwise specified, each component may be singular or plural. The position, size, shape, range, and the like of each component illustrated in the drawings may not represent the actual position, size, shape, range, and the like to facilitate understanding of the invention. In all the drawings for describing the embodiment, the same members are denoted by the same reference numerals in principle, and the repeated description thereof will be omitted. In addition, in the following embodiment, the components (including element steps and the like) are not necessarily essential unless otherwise clearly stated or unless they are considered, in principle, to be obviously essential. Furthermore, the phrases "consisting of A," "composed of A," "having A," and "including A" do not

exclude other components unless it is clearly stated that the components are exclusive. Similarly, in the following embodiment, references to the shapes, positional relationships, and the like of the components and the like include ones substantially approximate or similar to the shapes and the like, unless otherwise clearly stated or unless they are considered, in principle, to be obviously exclusive. In addition, "acquisition" includes at least generation, calculation, or reception from the outside by a subject, as a specific example.

[0015]

<Configuration example of paint drying control system 1 according to an embodiment of the present invention>

FIG. 1 illustrates a configuration example of a paint drying control system 1 according to the embodiment of the present invention. The paint drying control system 1 dries a painted object P using hot air generated by ammonia combustion.

[0016]

The paint drying control system 1 includes a paint drying apparatus 10 and a paint drying control apparatus 30.

[0017]

The paint drying apparatus 10 includes gas cylinders 11 to 13, flow rate adjustment mechanisms 14 to 16, a tubular furnace 17, a drying space 18, a gas concentration measurement unit 19, and an exhaust gas treatment facility

20.

[0018]

The gas cylinder 11 stores ammonia gas (NH_3) (with a concentration of 50 [%], for example) serving as fuel. The gas cylinder 12 stores air (AIR) to be mixed with ammonia gas for combustion. The gas cylinder 13 stores inert gas (e.g., nitrogen gas (N_2)) for suppressing combustion. Alternatively, instead of nitrogen gas, argon gas or air may be used as the inert gas.

[0019]

The flow rate adjustment mechanism 14 supplies the ammonia gas stored in the gas cylinder 11 to the tubular furnace 17 under the control of the paint drying control apparatus 30. Similarly, the flow rate adjustment mechanism 15 supplies the air stored in the gas cylinder 12 to the tubular furnace 17 under the control of the paint drying control apparatus 30. The flow rate adjustment mechanism 16 supplies the inert gas stored in the gas cylinder 13 to the tubular furnace 17 under the control of the paint drying control apparatus 30. In addition, the flow rate adjustment mechanisms 14 to 16 measure the temperature of each gas to be supplied to the tubular furnace 17, and output the temperature to the paint drying control apparatus 30 together with the flow rate of each gas.

[0020]

Note that the control of the flow rate adjustment

mechanisms 14 to 16 does not depend on the paint drying control apparatus 30, and a user may manually adjust the flow rate adjustment mechanisms 14 to 16 according to a control condition generated by the paint drying control apparatus 30.

[0021]

The tubular furnace 17 is formed so as to cover the drying space 18. The tubular furnace 17 generates hot air (drying atmosphere) at a predetermined temperature by burning mixed gas containing at least the ammonia gas supplied from the previous stage, and releases the hot air into the drying space 18. In addition, combustion in the tubular furnace 17 can be suppressed by supplying inert gas.

[0022]

In the drying space 18, the object P to which paint has been applied and that needs to be dried to cure the coating film is placed. Possible paint types include, for example, urethane paint, epoxy paint, alkyd paint, acrylic paint, and the like. The drying space 18 measures the temperature of the drying atmosphere and outputs the temperature to the paint drying control apparatus 30. The temperature of the drying atmosphere may be measured, for example, by installing a thermocouple in the drying space 18, or the temperature of the object P may be measured with a radiation thermometer.

[0023]

The gas concentration measurement unit 19 includes, for example, a detection tube, a chromatography device, a laser analysis device, and the like. The gas concentration measurement unit 19 measures the ammonia concentration in the drying atmosphere in the drying space 18 and outputs the ammonia concentration to the paint drying control apparatus 30.

[0024]

The exhaust gas treatment facility 20 includes, for example, a scrubber, an abatement furnace, and the like, and is a facility for removing harmful components of exhaust gas containing ammonia discharged from the drying space 18. In addition, the exhaust gas treatment facility 20 may be, for example, a mechanism that returns treated gas to a gas inflow side to circulate the gas. In addition, the exhaust gas treatment facility 20 may release the treated exhaust gas into the atmosphere after confirming that the environmental regulation value is met.

[0025]

The paint drying control apparatus 30 is connected to the paint drying apparatus 10 via a network N. The paint drying control apparatus 30 controls paint drying of the object P in the paint drying apparatus 10. The network N is a bidirectional communication network such as the Internet.

[0026]

FIG. 2 illustrates a configuration example of the

paint drying control apparatus 30. The paint drying control apparatus 30 includes, for example, a general computer such as a personal computer or a server computer. The computer includes a processor such as a central processing unit (CPU), a memory such as a dynamic random access memory (DRAM), a storage such as a hard disk drive (HDD) or a solid state drive (SSD), an input device such as a keyboard, a mouse, or a media drive, an output device such as a display, and a communication module such as an Ethernet (trademark) card or a Wi-Fi (trademark) adapter.

[0027]

The paint drying control apparatus 30 may be implemented by one physical or logical computer, or may be implemented by two or more physical or logical computers. The two or more physical or logical computers may be arranged on the network N in a distributed manner.

[0028]

The paint drying control apparatus 30 includes a processing device 31, a storage device 32, a communication device 33, an input device 34, and a display device 35.

[0029]

The processing device 31 is implemented by the processor of the computer constituting the paint drying control apparatus 30. The processing device 31 controls the entire paint drying control apparatus 30. The processing device 31 (processor) executes a program 321 in the storage device 32 to implement the functional blocks of

a UI control unit 311, a data acquisition unit 312, a threshold calculation unit 313, a determination unit 314, a control condition generation unit 315, and a flow rate control unit 316.

[0030]

The UI control unit 311 displays a UI screen 1000 (FIG. 4) on the display device 35, and receives an input from the user to the UI screen 1000. In addition, the UI control unit 311 displays the control condition generated by the control condition generation unit 315 on the UI screen 1000. Note that the generated control condition may not only be displayed on the UI screen 1000, but also, for example, be output to a terminal device or the like (not illustrated) used by an operator who operates the paint drying apparatus 10.

[0031]

The data acquisition unit 312 acquires the flow rate and the temperature of each gas from the flow rate adjustment mechanisms 14 to 16 of the paint drying apparatus 10. In addition, the data acquisition unit 312 acquires the temperature of the drying atmosphere from the drying space 18 of the paint drying apparatus 10. Furthermore, the data acquisition unit 312 acquires the ammonia concentration in the drying atmosphere from the gas concentration measurement unit 19 of the paint drying apparatus 10.

[0032]

The threshold calculation unit 313 substitutes the data acquired by the data acquisition unit 312 into a threshold function 322 stored in the storage device 32 to calculate an ammonia concentration threshold Th. An example of the threshold function 322 is expressed by the following formula (1).

[0033]

$$\text{Ammonia concentration threshold Th [\%]} = \{a \times (\text{drying time [min]}) \times (\text{paint type coefficient}) - b\} \times \{T / (\text{temperature of drying atmosphere [}^{\circ}\text{C]}) \dots (1)$$

a, b, and T are coefficients determined in advance based on experience or experiments.

[0034]

Alternatively, instead of the threshold function 322, for example, a table in which the concentration threshold Th is recorded in association with a combination of the drying time, the paint type coefficient, and the temperature of the drying atmosphere may be used.

[0035]

The determination unit 314 determines whether the ammonia concentration in the drying atmosphere is equal to or higher than the concentration threshold Th.

[0036]

When it is determined that the concentration of ammonia in the drying atmosphere is equal to or higher than the concentration threshold Th, the control condition generation unit 315 generates a control condition for

changing the flow rate of at least one of ammonia gas, air, and inert gas so that the concentration of ammonia in the drying atmosphere becomes lower than the concentration threshold Th . Specifically, for example, using the concentration threshold Th and at least one of the current flow rate of each gas, the temperature of each gas, the paint type, and the drying time as inputs, the control condition is generated from a function that outputs the flow rate of each gas as the control condition, a learning model learned in advance, or the like. When it is determined that the concentration of ammonia in the drying atmosphere is lower than the concentration threshold Th , the control condition generation unit 315 does not generate the control condition.

[0037]

The flow rate control unit 316 controls the flow rate adjustment mechanisms 14 to 16 of the paint drying apparatus 10 according to the generated control condition.

[0038]

The storage device 32 is implemented by the memory and storage of the computer constituting the paint drying control apparatus 30. The storage device 32 stores the program 321, the threshold function 322, and a coefficient 323 in the threshold function. The coefficient 323 includes the paint type coefficient corresponding to each possible paint type, and the coefficients a , b , and T in the formula (1). In addition, the storage device 32 may

store other information and data.

[0039]

The communication device 33 is implemented by the communication module of the computer constituting the paint drying control apparatus 30. The communication device 33 is connected to the paint drying apparatus 10 via the network N, and communicates various data and information.

[0040]

The input device 34 is implemented by the input device of the computer constituting the paint drying control apparatus 30. The input device 34 receives various inputs from the user.

[0041]

The display device 35 is implemented by the output device of the computer constituting the paint drying control apparatus 30. The display device 35 displays the UI screen 1000 under the control of the UI control unit 311.

[0042]

<Paint drying control processing by paint drying control system 1>

FIG. 3 is a flowchart for describing an example of paint drying control processing by the paint drying control system 1.

[0043]

First, assume that the object P to which paint has been applied is placed in the drying space 18 of the paint

drying apparatus 10. In addition, assume that the flow rate control unit 316 of the paint drying apparatus 10 holds an initial value of the flow rate of each gas in the flow rate adjustment mechanisms 14 to 16 of the paint drying apparatus 10.

[0044]

The paint drying control processing is started, for example, in response to a predetermined operation from the user.

[0045]

First, the UI control unit 311 acquires the paint type and the drying time input by the user on the UI screen 1000 (FIG. 5) displayed on the display device 35 (step S1).

[0046]

Next, the flow rate control unit 316 controls the flow rate adjustment mechanisms 14 to 16 of the paint drying apparatus 10 to supply each gas to the tubular furnace 17 with the initial value of each flow rate, and starts combustion of the mixed gas in the tubular furnace 17. As a result, hot air (drying atmosphere) obtained by combustion is released to the drying space 18 (step S2).

[0047]

Next, the data acquisition unit 312 acquires the flow rate and the temperature of each gas to the tubular furnace 17 from the flow rate adjustment mechanisms 14 to 16. In addition, the data acquisition unit 312 acquires the temperature of the drying atmosphere from the drying space

18 of the paint drying apparatus 10 (step S3).

[0048]

Next, the threshold calculation unit 313 substitutes the drying time, the paint type coefficient corresponding to the paint type, and the temperature of the drying atmosphere acquired by the data acquisition unit 312 into the threshold function 322 read from the storage device 32 to calculate the ammonia concentration threshold Th (step S4).

[0049]

Next, the data acquisition unit 312 acquires the ammonia concentration in the drying atmosphere from the gas concentration measurement unit 19 of the paint drying apparatus 10 (step S5).

[0050]

Next, the determination unit 314 determines whether the ammonia concentration acquired in step S5 in the drying atmosphere is equal to or higher than the concentration threshold Th calculated in step S4 (step S6).

[0051]

Here, when it is determined that the concentration of ammonia in the drying atmosphere is equal to or higher than the concentration threshold Th (YES in step S6), the control condition generation unit 315 generates the control condition for changing the flow rate of at least one of the gases so that the concentration of ammonia in the drying atmosphere becomes lower than the concentration threshold

Th. Then, the UI control unit 311 displays the generated control condition on the UI screen 1000 (step S7).

[0052]

Next, the flow rate control unit 316 controls the flow rate adjustment mechanisms 14 to 16 of the paint drying apparatus 10 according to the generated control condition to adjust the flow rate of each gas (step S8).

[0053]

When it is determined in step S6 that the concentration of ammonia in the drying atmosphere is lower than the concentration threshold Th (NO in step S6), steps S7 and S8 are skipped, and the flow rate of each gas is not adjusted (the current flow rate is maintained).

[0054]

According to the paint drying control processing described above, since the flow rate of each gas is adjusted so that the concentration of ammonia in the drying atmosphere becomes lower than the concentration threshold Th, it is possible to prevent ammonia in the drying atmosphere from chemically inhibiting the formation of the coating film and deteriorating the coating film quality.

[0055]

Note that the paint drying control processing may be performed by repeating steps S3 to S8 at a predetermined cycle during a time when the object P is dried. In this case, in the generation of the control condition in step S7, the flow rate of ammonia gas may be decreased by a

predetermined amount, and the flow rate of air and inert gas may be increased by a predetermined amount without specifying the flow rate of each gas. In addition, the paint drying control processing may be performed at any timing.

[0056]

<Display example of UI screen 1000>

FIG. 4 illustrates a display example of the UI screen 1000 displayed on the display device 35 by the UI control unit 311.

[0057]

The UI screen 1000 is provided with an input field 1001 for the user to input the paint type, an input field 1002 for the user to input the drying time, a display field 1003 for displaying the temperature of the drying atmosphere, and 1004 for displaying the calculated concentration threshold Th . In addition, the input field 1001 may be such that the paint type can be selectively input. The input field 1002 may be such that the drying time can be selectively input.

[0058]

Furthermore, the UI screen 1000 is provided with a display field 1010 for displaying the flow rate of each gas before control (before adjustment) and the ammonia concentration measured from the drying atmosphere, and a display field 1011 for displaying the flow rate of each gas serving as the control condition and the ammonia

concentration measured from the estimated drying atmosphere.

[0059]

The user can check the flow rate of each gas on the UI screen 1000.

[0060]

Note that step S8 of the paint drying control processing (FIG. 3) may be omitted, and as described above, the user may check the display field 1011 on the UI screen 1000 and manually adjust the flow rate adjustment mechanisms 14 to 16.

[0061]

The present invention is not limited to the above-described embodiment, and various modifications can be made. For example, the above-described embodiment has been described in detail to describe the present invention in an easily understandable manner, and is not necessarily limited to one including all the above-described components. In addition, some of the components of one embodiment can be replaced with the components of another embodiment, and the components of another embodiment can be added.

[0062]

For the control lines and the information lines, ones considered to be necessary for the description are indicated, and all the control lines and the information lines necessary for the implementation are not always

indicated. In practice, it may be considered that almost all the components are connected to each other.

What is claimed is:

1. A paint drying control apparatus that controls a paint drying apparatus for drying a painted object, the paint drying control apparatus comprising
 - a storage device and a processing device, wherein the storage device stores a paint type coefficient corresponding to a paint type, and the processing device receives an input of a paint type used to paint the object and a drying time of the object that have been input from a user, acquires a temperature of a drying atmosphere for drying the object and an ammonia concentration in the drying atmosphere that have been obtained by burning mixed gas containing at least ammonia gas in a combustion furnace in the paint drying apparatus, calculates an ammonia concentration threshold of the ammonia gas based on the drying time, the paint type coefficient corresponding to the paint type used to paint the object, and the temperature of the drying atmosphere, generates a control condition related to a change in a flow rate of each gas constituting the mixed gas to the combustion furnace when the acquired ammonia concentration in the drying atmosphere is equal to or higher than the ammonia concentration threshold, and outputs the generated control condition.

2. The paint drying control apparatus according to claim 1, wherein

the processing device generates the control condition based on the ammonia concentration threshold, and at least one of a current flow rate of the each gas, a temperature of the each gas, the paint type, and the drying time.

3. The paint drying control apparatus according to claim 2, wherein

the processing device generates the control condition from a function that outputs the flow rate of the each gas as the control condition or a learning model learned in advance, using the ammonia concentration threshold, and at least one of the current flow rate of the each gas, the temperature of the each gas, the paint type, and the drying time as an inputs.

4. The paint drying control apparatus according to claim 1, wherein

the each gas constituting the mixed gas contains either air or inert gas, or both in addition to the ammonia gas.

5. The paint drying control apparatus according to claim 1, wherein

the processing device inputs the drying time, the paint type coefficient corresponding to the paint type, and the temperature of the drying atmosphere to a predetermined threshold function to calculate the ammonia concentration threshold of the ammonia gas.

6. The paint drying control apparatus according to claim 5, wherein

the predetermined threshold function is expressed by the following formula:

ammonia concentration threshold Th [%] = { $a \times (\text{drying time [min]}) \times (\text{paint type coefficient}) - b$ } $\times$ { $T/(\text{temperature of drying atmosphere } [^{\circ}\text{C}])$ },

where a , b , and T are coefficients determined in advance based on experience or experiments.

7. The paint drying control apparatus according to claim 1, wherein

the processing device:

controls a flow rate of the each gas to the combustion furnace at the paint drying apparatus according to the generated control condition.

8. A paint drying control method by a paint drying control apparatus that controls a paint drying apparatus for drying a painted object, the method comprising the steps of:

receiving an input of a paint type used to paint the object and a drying time of the object that have been input from a user;

acquiring a temperature of a drying atmosphere for drying the object and an ammonia concentration in the drying atmosphere that have been obtained by burning mixed gas containing at least ammonia gas in a combustion furnace in the paint drying apparatus;

calculating an ammonia concentration threshold of the

ammonia gas based on the drying time, a paint type coefficient corresponding to the paint type used to paint the object, and the temperature of the drying atmosphere;

generating a control condition related to a change in a flow rate of each gas constituting the mixed gas to the combustion furnace when the acquired ammonia concentration in the drying atmosphere is equal to or higher than the ammonia concentration threshold; and

outputting the generated control condition.

9. A paint drying control system comprising:

a paint drying apparatus for drying a painted object;

and

a paint drying control apparatus that controls the paint drying apparatus, wherein

the paint drying apparatus

generates a drying atmosphere used to dry the object by burning mixed gas containing at least ammonia gas in a combustion furnace, and measures a temperature of the drying atmosphere and an ammonia concentration in the drying atmosphere,

the paint drying control apparatus

includes the storage device and the processing device,

the storage device

stores a paint type coefficient corresponding to a paint type, and

the processing device

receives an input of a paint type used to paint the object and a drying time of the object input from a user,
acquires the temperature of the drying atmosphere and the ammonia concentration in the drying atmosphere in the paint drying apparatus,
calculates an ammonia concentration threshold of the ammonia gas based on the drying time, the paint type coefficient corresponding to the paint type used to paint the object, and the temperature of the drying atmosphere,
generates a control condition related to a change in a flow rate of each gas constituting the mixed gas to the combustion furnace when the acquired ammonia concentration in the drying atmosphere is equal to or higher than the ammonia concentration threshold, and
outputs the generated control condition.