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(54) **SYSTEM AND METHOD FOR EVALUATING OPERATIONAL CONDITIONS OF BLAST FURNACE**

SYSTEM UND VERFAHREN ZUR BEWERTUNG DER BETRIEBSBEDINGUNGEN EINES
HOCHOFENS

SYSTÈME ET PROCÉDÉ D'ÉVALUATION DES CONDITIONS DE FONCTIONNEMENT D'UN HAUT
FOURNEAU

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Description

[Technical Field]

[0001] The present disclosure relates to a system and a method for evaluating operational conditions of a blast furnace.

[Background Art]

[0002] In order to evaluate operational conditions of a blast furnace, attempts have been made to determine a situation inside a furnace by analyzing image data captured through a tuyere of the blast furnace, or the like, or to determine a situation inside a furnace by monitoring operational data.

[0003] However, in the related art, an operator has merely qualitatively judged the blast furnace combustibility or the blast furnace condition simply through image data, or merely judged the situation inside the furnace by analyzing luminance of the image data.

[0004] In this regard, JP 2015 - 52 148 A (published date: March 19, 2015) discloses a control method based on determination of operational conditions of a furnace.

[0005] The teaching of JP 2016 - 060 931 A serves for an accurately observation of a condition near a blast furnace tuyere independently from fluctuation in a blast furnace tuyere image due to fire. JP 2016 - 060 931 A discloses a method for observing a condition in a blast furnace tuyere by utilizing a thermal radiation intensity image taken by an imaging apparatus arranged on the blast furnace tuyere, comprising: a step of identifying an ellipse shape matching with an outline shape by applying ellipse shapes to an outline shape of a tuyere from each of thermal radiation intensity images; a step of carrying out geometric transformation to each of thermal radiation intensity images to generate a normalized image and carrying out polar conversion to the normalized image with ellipse parameters of the identified ellipse shape so that each of outline shapes to be a normalized circle having a determined center position and a determined radius; a step of generating a binarized image by binarizing the normalized image after polar conversion generated; and a step of generating light part distribution information showing distribution in the radial direction of a normalized circle of light parts present in the generated binarized image by utilizing the binarized image generated.

[0006] JP 2015 - 048 508 A provides a method for more easily observing the state of a blast furnace tuyere including the steps of: creating a normalized image through geometric transformation to make a normalized circle of the shape profile of a tuyere in a thermal radiation brightness image and polar transforming the normalized image; creating a binarized image through binarization of the normalized image after the polar transformation; creating bright part distribution data which indicate the distribution of the bright parts existing in the binarized image in the radial direction of the normalized circle; calculating

the feature quantity data including the element number as feature quantity for defining the number of elements contained in the predetermined range in the radial direction and the position in the radial direction as feature quantity for indicating the largest number of elements in the radial direction, based on the bright part distribution data; and calculating the index for defining the state in the tuyere by setting a two-dimensional coordinate system specified from the element number as feature quantity and the position in the radial direction as feature quantity and by presuming that the set of feature quantity data on a plurality of the thermal radiation brightness images has a distribution in an approximately triangle shape in the coordinate system of the feature quantities.

[0007] EP 3 029 160 A1 teaches an abnormality detection device 10 including tuyere cameras 31 installed in the vicinities of a plurality of tueres 11 of the blast furnace 1 and an image processing device 7. A representative brightness vector collection unit 773 of the image processing device 7 determines representative brightnesses based on brightness values of respective pixels for the tueres images previously shot by the tuyere cameras 31 at the same time so as to collect representative brightness vectors in a time-series manner. An index extraction unit 775 performs principal component analysis on the representative brightness vectors collected in the time-series manner so as to extract a principal component vector. The representative brightness vector collection unit 773 collects the representative brightness vector from tuyere images shot by the tuyere cameras 31 at the same time during an operation. The abnormality detection processor 777 calculates a length of a normal line drawn from the collected representative brightness vector in the direction of the principal component vector as an evaluation value and compares the evaluation value with a predetermined threshold so as to detect the abnormality of the blast furnace 1.

[Disclosure]

[Technical Problem]

[0008] In the technical field, a method for quantitatively evaluating a combustion state of a tuyere based on the tuyere image data, and based thereon, a method for integrally evaluating operational conditions of a blast furnace is required.

[Technical Solution]

[0009] In order to solve the above problems, an embodiment of the present disclosure is to provide a system for evaluating operational conditions of a blast furnace.

[0010] According to an embodiment of the present disclosure, a system and a method for evaluating operational conditions of a blast furnace includes: an image capturing unit for capturing image data according to each of a plurality of tueres disposed in a blast furnace; an image

collection unit for collecting the image data captured according to each of the tuyeres by the image capturing unit; a tuyere combustion state determination unit for classifying, on the basis of artificial intelligence, combustion states according to each of the tuyeres by using the image data according to each of the tuyeres; a tuyere combustion state index generation unit for generating combustion state indices according to each of the tuyeres by using the result of classifying the combustion states according to each of the tuyeres by the tuyere combustion state determination unit; and an integrated evaluation unit for generating an integrated combustion state index on the basis of the combustion state indices according to each of the tuyeres, characterized in that,

the tuyere combustion state determination unit (130) comprises an AI-based determination unit (131) for classifying combustion states according to each of the tuyeres (11) based on deep learning using the image data according to each of the tuyeres; wherein the AI-based determination unit (131) determines the combustion state classification according to each of the tuyeres (11) based on a result of accumulating a result of classifying the combustion states according to each of the tuyeres classified based on deep learning in time series for a predetermined time period; wherein the time period is adjusted according to elapsed time information from a time at which the tuyere combustion state classification is first detected to a time at which the tuyere combustion state classification transitions to another state; wherein the combustion state classification comprises a normal combustion state, a poor combustion state, pulverized coal non-injection, unreduced molten material falling, and coke turning; wherein the combustion state index according to each of the tuyeres comprises at least one of a combustion state defect index, a pulverized coal noninjection index, an unreduced molten material falling index, a coke turning index, a combustion state level index, a pulverized coal flow rate index, and a tuyere raceway index.

[0011] Meanwhile, another embodiment of the present disclosure is to provide a method for evaluating operating conditions a blast furnace.

[0012] According to another embodiment of the present disclosure, the method for evaluating operating conditions a blast furnace includes operations of: collecting image data according to a plurality of tuyeres provided in a blast furnace; classifying combustion states according to each of the tuyeres on the basis of artificial intelligence, by using the image data according to each of the tuyeres; generating combustion state indices according to each of the tuyeres by using the result of classifying the combustion state according to a plurality of tuyeres;

and generating an integrated combustion state index on the basis of the combustion state indices according to each of the tuyeres,

determining a combustion state classification according to each of the tuyeres based on a result of accumulating the result of classifying the combustion state according to each of the tuyeres classified based on the deep learning for a predetermined time period; and adjusting the time period according to elapsed time information from a time at which the tuyere combustion state classification is first detected to a time at which the tuyere combustion state classification transitions to another state; wherein, at the time of initial performance, starting from the time at which the classification of the combustion state of the corresponding tuyere is first detected, the tuyere combustion state classification may be determined by accumulating the results primarily classified for a time period set by a user and when the determination result of the tuyere combustion state classification is accumulated, the time period is adjusted according to the elapsed time information from the time information from the time at which the tuyere combustion state classification is first detected to the time at which the tuyere combustion state classification transitions to another state; wherein the combustion state classification comprises a normal combustion state, a poor combustion state, pulverized coal non-injection, unreduced molten material falling, and coke turning; wherein the combustion state index according to each of the tuyeres comprises at least one of a combustion state defect index, a pulverized coal noninjection index, an unreduced molten material falling index, a coke turning index, a combustion state level index, a pulverized coal flow rate index, and a tuyere raceway index.

[0013] In addition, not all features of the present disclosure are listed in the solution means of the above-mentioned problem. Various features of the present disclosure and the advantages and effects thereof may be understood in more detail with reference to specific embodiments below.

[Advantageous Effects]

[0014] According to an embodiment in the present disclosure, it is possible to classify a tuyere combustion state based on deep learning using the tuyere image data, in addition to the result of classifying the result of classifying the tuyere combustion state, and a result of analyzing the tuyere image data and a result of analyzing the blast furnace operational data may be additionally used to extract the tuyere combustion state indices according to

each of the tuyeres, and an operational condition of a blast furnace may be integrally evaluated and controlled.

[0015] Accordingly, the blast furnace combustibility and the blast furnace condition may be quantitatively evaluated to enable stable blast furnace operations, and productivity may be improved.

[Description of Drawings]

[0016]

FIG. 1 is a configuration diagram of a system for evaluating operational conditions of a blast furnace according to an embodiment of the present disclosure.

FIG. 2 is a view illustrating a concept for primarily classifying a tuyere combustion state on the basis of deep learning according to an embodiment of the present disclosure.

FIGS. 3 and 4 are views diagrams illustrating a concept of determining classification of a tuyere combustion state on the basis of accumulating results primarily classified in time series based on deep learning according to an embodiment of the present disclosure.

FIG. 5 is a flowchart of a method for evaluating operating conditions according to another embodiment of the present disclosure.

[Best Mode for Invention]

[0017] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The disclosure may, however, be exemplified in many different forms and should not be construed as being limited to the specific embodiments set forth herein, and those skilled in the art and understanding the present disclosure can easily accomplish retrogressive inventions or other embodiments included in the scope of the present disclosure by the addition, modification, and removal of components within the same scope, but those are construed as being included in the scope of the present disclosure. Like reference numerals will be used to designate like components having similar functions throughout the drawings within the scope of the present disclosure.

[0018] Throughout the specification, it will be understood that when an element is referred to as being "on," "connected to," or "coupled to" another element, it can be directly "on," "connected to," or "coupled to" the other element or indirectly "on," "connected to," or "coupled to" the other elements intervening therebetween may be present. In addition, when a component is referred to as "comprise" or "comprising," it means that it may include other components as well, rather than excluding other components, unless specifically stated otherwise.

[0019] FIG. 1 is a configuration diagram of a system for evaluating operational conditions of a blast furnace

according to an embodiment of the present disclosure.

[0020] Referring to FIG. 1, a system 100 for evaluating operational conditions of a blast furnace according to an embodiment of the present disclosure may be configured to include an image capturing unit 110, an image collection unit 120, a tuyere combustion state determination unit 130, a tuyere combustion state index generation unit 140, an operational information collection unit 150, an integrated evaluation unit 160, and a blast furnace condition control unit 170.

[0021] The image capturing unit 110 acquires image data according to each of the tuyeres 11 provided in the blast furnace 10.

[0022] For example, the image capturing unit 110 may include a plurality of cameras installed in each tuyere 11, and may acquire the image data according to each of the tuyeres in real time (e.g., in ms units) through each camera.

[0023] The image collection unit 120 collects image data according to each of the tuyeres captured by the image capturing unit 110.

[0024] For example, the image collection unit 120 may collect image data obtained in real time according to each of the tuyeres from a plurality of cameras included in the image capturing unit 110.

[0025] In addition, the image collection unit 120 may map the collected image data with collection environment information including a tuyere number, data capture time, and the like.

[0026] In addition, the image data, which has been mapped by the image collection unit 120, may be stored in a data storage (not shown) provided in a system for evaluating operational conditions of a blast furnace 100, or may be transmitted in real time to the tuyere combustion state determination unit 130.

[0027] The tuyere combustion state determination unit 130 is for classifying a combustion state according to each of the tuyeres using the image data according to each of the tuyeres transmitted from the image collection unit 120, and is configured to include an AI-based determination unit 131 and an image processing-based determination unit 132.

[0028] The AI-based determination unit 131 classifies the combustion state according to each of the tuyeres based on artificial intelligence using the image data according to each of the tuyeres. For example, the AI-based determination unit 131 classifies the combustion state according to each of the tuyeres based on deep learning.

[0029] According to an embodiment, the AI-based determination unit 131 may primarily classify the combustion state according to each of the tuyeres based on a convolutional neural network (CNN) using image data according to each of the tuyeres.

[0030] If necessary, the AI-based determination unit 131 determines the tuyere combustion state classification based on results of accumulating the results of classifying the combustion states according to each of the tuyeres in time series, primarily classified, thereby further

improving consistency of the combustion state classification.

[0031] The concept of classifying and determining the tuyere combustion state by the AI-based determination unit 131 will be described in more detail with reference to FIGS. 2 to 4.

[0032] FIG. 2 is a view illustrating the concept of primarily classifying a tuyere combustion state based on deep learning according to an embodiment of the present disclosure.

[0033] Referring to FIG. 2, the AI-based determination unit 131 may classify the combustion states based on the image deep learning, for example, CNN, for first tuyere image to the Nth tuyere image data (21 to 2N) captured according to each of the tuyeres, thereby obtaining the results of the first tuyere combustion state classification to the Nth tuyere combustion state classification (21' to 2N'). Here, N means the number of tuyere.

[0034] FIGS. 3 and 4 are diagrams illustrating a concept of determining a tuyere combustion state classification based on a result of accumulating a result primarily classified based on deep learning in time series according to an embodiment of the present disclosure.

[0035] First, referring to FIG. 3, as a result of accumulating the result of classifying the combustion states in time series, primarily classified according to each of the tuyeres, that is, the AI-based determination unit 131 may determine a tuyere combustion state classification according to each of the tuyeres based on first tuyere combustion state classifications 31-1, 31-2, and 31-3, second tuyere combustion state classifications 32-1, 32-2, and 32-3, and Nth tuyere combustion state classifications 3N-1, 3N-2, and 3N-3, and may obtain determined tuyere combustion state classification results 31' to 33'.

[0036] In the present embodiment, if any combustion state classification occurs more than a predetermined number of times, a result of classifying the plurality of combustion states primarily classified for an arbitrary time period (t-1 to t+1) to determine the tuyere combustion state classification, may be determined as the corresponding combustion state classification. Thereby, it is possible to further improve the accuracy of the tuyere combustion state classification.

[0037] Next, referring to FIG. 4, as a result of accumulating the result of classifying the combustion states in time series, primarily classified according to each of the tuyeres, that is, the AI-based determination unit 131 may determine tuyere combustion state classification according to each of the tuyeres based on deep learning in time series on first tuyere combustion state classifications 41-1, 41-2, and 41-3, second tuyere combustion state classifications 42-1, 42-2, and 42-3, and Nth tuyere combustion state classifications 4N-1, 4N-2, and 4N-3, and may obtain determined tuyere combustion state classification results 41' to 43'.

[0038] For example, the AI-based determination unit 131 determine the tuyere combustion state classification according to each of the tuyeres based on a recurrent

neural network (RNN) or a recurrent convolutional neural network (RCNN) by using the result of classifying a plurality of combustion states primarily classified according to each of the tuyeres for an arbitrary time period (t-1 to t+1).

[0039] Since the combustion state of the tuyere changes with continuity over time, the accuracy may be deteriorated to determine the combustion state of the tuyere only at a certain point in time.

[0040] Therefore, according to the present embodiment, in order to determine the combustion state classification of the tuyere by comprehensively considering the changes in the combustion state of the tuyere according to the time flow, an image time-series deep learning may be applied to further improve the accuracy of the tuyere combustion state classification.

[0041] Meanwhile, as illustrated in FIGS. 3 and 4, in determining the tuyere combustion state classification based on the results accumulated in time series, the accuracy of classification may be affected according to the time period (for example, t-1 to t+1) for accumulating the results primarily classified and a start time (t-1) of the corresponding time period.

[0042] According to an embodiment, at the time of initial performance, starting from the time at which the classification of the combustion state of the corresponding tuyere is first detected, the tuyere combustion state classification is determined by accumulating the results primarily classified for a time period set by a user.

[0043] In addition, when the determination result of the tuyere combustion state classification is accumulated, the above-described time period is adjusted according to the elapsed time information from the time at which the tuyere combustion state classification is first detected to the time at which the tuyere combustion state classification transitions to another state, such that the accuracy may be further improved.

[0044] The tuyere combustion state classified by the AI-based determination unit 131 includes a normal combustion state, a poor combustion state, pulverized coal non-injection, unreduced molten material falling (raw ore falling), coke turning, and the like.

[0045] Here, pulverized coal non-injection means that it is determined whether or not pulverized coal is injected, unreduced molten material falling (raw ore falling) means that it is determined whether or not an unreduced raw material in a molten state in which raw materials that need to be reduced in an upper part of the furnace are unreduced and fall, and coke turning means whether coke turns in a middle part of the coke.

[0046] The image processing-based determination unit 132 may diagnose a tuyere facility through image processing for image data according to each of the tuyeres, and determine the tuyere combustion state.

[0047] According to an embodiment, the image processing-based determination unit 132 may determine a tuyere facility abnormal condition including presence or absence of a curvature of a tuyere, presence or ab-

sence of a tuyere attachment, clogging or a tuyere, lance banding or burning, or the like, through image processing of the image data according to each of the tuyeres.

[0048] In addition, the image processing-based determination unit 132 may extract a combustion area and combustion brightness (i.e., luminance) through image processing of image data according to each of the tuyeres.

[0049] In addition, when the combustion state is normal, the image processing-based determination unit 132 may determine a pulverized coal flow rate through image processing of the image data according to each of the tuyeres.

[0050] Various image processing techniques known to a person skilled in the art may be applied to the image processing-based determination unit 132 for image processing of image data according to each of the tuyeres, and detailed description thereof will be omitted.

[0051] The determination by the AI-based determination unit 131 and the image processing-based determination unit 132 described above may be performed in parallel.

[0052] The combustion condition classification result according to each of the tuyeres classified by the tuyere combustion state determination unit 130 and the tuyere facility diagnosis result may be mapped and stored and managed together with image data and collection environment information according to each of the tuyeres.

[0053] The tuyere combustion state index generation unit 140 generates a combustion state index according to each of the tuyeres by using the combustion state classification result according to each of the tuyeres classified by the tuyere combustion state determination unit 130.

[0054] According to an embodiment, the combustion state index according to each of the tuyeres generated by the tuyere combustion state index generation unit 140 includes a combustion state defect index, a pulverized coal non-injection index, an unreduced molten material falling(raw ore falling) index, a coke turning index, a combustion state level index, a pulverized coal flow rate index, a tuyere raceway index, and the like.

[0055] For example, the tuyere combustion state index generation unit 140 may count the number of times that an arbitrary classification result has occurred based on the combustion state classification results according to each of the tuyeres by the tuyere combustion state determination unit 130 for every predetermined period, and generate a related index by scoring it according to the number of times counted for each corresponding period.

[0056] In addition, the tuyere combustion state index generation unit 150 may score the combustion state level index according to a combustion area and combustion brightness (i.e., luminance) extracted by the tuyere combustion state determination unit 130, combine the calculated scores for a predetermined period to generate a combustion state level index. Here, reference information used to generate the combustion state level index can be updated according to the input signal by the ad-

ministrator. Accordingly, the updated reference information may be reflected in real time to generate index information reflecting the blast furnace condition.

[0057] In addition, the tuyere combustion state index generation unit 140 may generate a tuyere facility abnormality index by scoring the results of the tuyere facility diagnosis determined by the tuyere combustion state determination unit 130. Here, the tuyere facility abnormality index may include a tuyere curvature index, a tuyere attachment index, a tuyere blockage index, a lance damage index, and the like.

[0058] An operational information collection unit 150 is for collecting operational information generated during a blast furnace operation in real time. Here, the operational information may include, for example, a blast furnace body temperature, pressure, a cooling water flow rate, and the like.

[0059] The operational information collected in real time by the operational information collection unit 150 may be mapped with the tuyere combustion state index information generated by the tuyere combustion state index information unit 140 described above and stored and managed.

[0060] An integrated evaluation unit 160 may be integrally evaluated in a circumferential direction of the blast furnace based on the tuyere operational state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140 and operational information collected by an operational information collection unit 150.

[0061] According to an embodiment, the integrated evaluation unit 160 generates an integrated combustion state index by comprehensively considering the tuyere combustion state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140.

[0062] For example, the integrated combustion state index may include an integrated combustion state index, matched 1:1 to the integrated combustion state index generated according to each of the tuyeres such as an integrated combustion state defect index, an integrated pulverized coal non-injection index, an integrated unreduced molten material falling(raw ore falling)index, and the like.

[0063] In addition, the integrated evaluation unit 160 may generate a circumferential balance index based on tuyere raceway indices generated according to each of the tuyeres.

[0064] In addition, the integrated evaluation unit 160 may generate an integrated tuyere facility abnormality index based on the tuyere facility abnormality index generated according to each of the tuyeres.

[0065] A blast furnace condition control unit 170 may perform at least one of pulverized coal injection control, N₂ purge control, and blast furnace charge control, based on the tuyere combustion state index information generated according to each of the tuyeres by the tuyere combustion state index generation unit 140 or the integrated

combustion state index generated by the integrated evaluation unit 160 to control the blast furnace condition.

[0066] According to an embodiment, the blast furnace condition control unit 170 may perform pulverized coal injection control when a pulverized coal non-injection index for an arbitrary tuyere exceeds a predetermined reference value.

[0067] In addition, the blast furnace condition control unit 170 may perform blast furnace charging control when a unreduced molten material falling (raw ore falling) index exceeds a predetermined reference value due to occurrence of raw ore falling in any tuyere region.

[0068] According to another embodiment, the blast furnace condition control unit 170 may integrally control a plurality of tuyeres based on information of an integrated combustion state index or a circumferential balance index.

[0069] For example, the blast furnace control unit 170 may control a blast furnace charging, for example, by changing distribution of charges to change a direction in which the charges fall, when raw ore falling occurs in only one direction.

[0070] The system for evaluating operational conditions of a blast furnace 100 described above with reference to FIG. 1 applies an artificial intelligence algorithm to input data and performs image processing, and may be implemented by combination of a processing device capable of calculating various indices, and a control device capable of performing blast furnace control.

[0071] FIG. 5 is a flowchart of a method for evaluating operational conditions of a blast furnace according to another embodiment of the present disclosure.

[0072] Referring to FIG. 5, according to a method for evaluating operational conditions of a blast furnace, image data according to each of the tuyeres provided in a blast furnace may be collected in real time by an image capturing unit 110 and an image collection unit 120 (S510).

[0073] Thereafter, by a tuyere combustion state determination unit 130, a combustion state according to each of the tuyeres is classified using the image data according to each of the tuyeres (S520).

[0074] Specifically, by an AI-based determination unit 131, after primarily classifying the tuyere combustion state based on artificial intelligence using the image data according to each of the tuyeres (S521), the classification of the tuyere combustion state is determined based on the result of classifying the combustion states (S522).

[0075] In addition, in parallel therewith, by an image processing-based determination unit 132, in addition to classifying the combustion state according to each of the tuyeres through image processing for the image data according to each of the tuyeres, a tuyere facility can be diagnosed (S525).

[0076] Thereafter, by a tuyere combustion state index generation unit 140, a combustion state index is generated based on the result of classifying the combustion state according to each of the tuyeres (S530), and by an

integrated evaluation unit 160, an operational condition of a blast furnace may be integrally evaluated in a circumferential direction based on the generated combustion state index according to each of the tuyeres (S540).

[0077] Thereafter, by a blast furnace condition control unit 170, a blast furnace condition may be controlled based on the integrally evaluated operational condition (S550).

[0078] Since the detailed method of performing each operation described above with reference to FIG. 5 is the same as described above with reference to FIGS. 1 to 4, redundant description thereof will be omitted.

[0079] While embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A system (100) for evaluating operational conditions of a blast furnace, comprising:

an image capturing unit (110) for capturing image data according to each of a plurality of tuyeres (11) provided in a blast furnace;

an image collection unit (120) for collecting the image data captured according to each of the tuyeres (11) by the image capturing unit (110);

a tuyere combustion state determination unit (130) for classifying, on the basis of artificial intelligence, combustion states according to each of the tuyeres (11), by using the image data according to each of the tuyeres;

a tuyere combustion state index generation unit (140) for generating a combustion state index according to each of the tuyeres (11) by using the result of classifying the combustion states according to each of the tuyeres by the tuyere combustion state determination unit (130); and an integrated evaluation unit (160) for generating an integrated combustion state index on the basis of the combustion state index according to each of the tuyeres,

characterized in that,

the tuyere combustion state determination unit (130) comprises an AI-based determination unit (131) for classifying combustion states according to each of the tuyeres (11) based on deep learning using the image data according to each of the tuyeres;

wherein the AI-based determination unit (131) determines the combustion state classification according to each of the tuyeres (11) based on a result of accumulating a result of classifying the combustion states according to each of the tuyeres classified based on deep learning in time

- series for a predetermined time period;
 wherein the time period is adjusted according to
 elapsed time information from a time at which
 the tuyere combustion state classification is first
 detected to a time at which the tuyere combus- 5
 tion state classification transitions to another
 state;
 wherein the combustion state classification
 comprises a normal combustion state, a poor 10
 combustion state, pulverized coal non-injection,
 unreduced molten material falling, and coke
 turning;
 wherein the combustion state index according
 to each of the tuyeres comprises at least one of
 a combustion state defect index, a pulverized 15
 coal noninjection index, an unreduced molten
 material falling index, a coke turning index, a
 combustion state level index, a pulverized coal
 flow rate index, and a tuyere raceway index. 20
2. The system (100) for evaluating operational condi-
 tions of a blast furnace of claim 1, wherein the AI-
 based determination unit (131) determines the com-
 bustion state classification if any combustion state 25
 classification occurs more than a predetermined
 number of times during the time period.
3. The system (100) for evaluating operational condi-
 tions of a blast furnace of claim 1, wherein the tuyere
 combustion state determination unit (130) further 30
 comprises an image processing-based determina-
 tion unit (132) for diagnosing a tuyere facility through
 image processing on the image data according to
 each of the tuyeres and determining the tuyere com-
 bustion state. 35
4. The system (100) for evaluating operational condi-
 tions of a blast furnace of claim 1, further comprising
 a blast furnace condition control unit (170) for per-
 forming at least one of pulverized coal injection control, 40
 N₂ purge control, and blast furnace charge control,
 based on the combustion state index according
 to each of the tuyeres or the integrated combustion
 state index. 45
5. A method for evaluating operational conditions of a
 blast furnace comprising operations of:
- collecting image data according to a plurality of
 tuyeres provided in a blast furnace (S510); 50
 classifying a combustion state according to each
 of the tuyeres based on artificial intelligence us-
 ing the image data according to each of the tuy-
 eres (S520);
 generating a combustion state index according 55
 to each of the tuyeres using the result of classifi-
 cation of the combustion state according to each of
 the tuyeres (S530); and

generating an integrated combustion state index
 based on the combustion state index according
 to each of the tuyeres (S540),
 wherein the operation of classifying the combus-
 tion state according to each of the tuyeres com-
 prises operations of:

classifying the combustion state according
 to each of the tuyeres based on deep learn-
 ing using the image data according to each
 of the tuyeres;
 determining a combustion state classifica-
 tion according to each of the tuyeres based
 on a result of accumulating the result of class-
 ifying the combustion state according to
 each of the tuyeres classified based on the
 deep learning for a predetermined time pe-
 riod; and
 adjusting the time period according to
 elapsed time information from a time at
 which the tuyere combustion state classifi-
 cation is first detected to a time at which the
 tuyere combustion state classification transi-
 tions to another state;
 wherein, at the time of initial performance,
 starting from the time at which the classifi-
 cation of the combustion state of the corre-
 sponding tuyere is first detected, the tuyere
 combustion state classification may be de-
 termined by accumulating the results prima-
 rily classified for a time period set by a user
 and when the determination result of the
 tuyere combustion state classification is ac-
 cumulated, the time period is adjusted ac-
 cording to the elapsed time information from
 the time information from the time at which
 the tuyere combustion state classification is
 first detected to the time at which the tuyere
 combustion state classification transitions
 to another state;
 wherein the combustion state classification
 comprises a normal combustion state, a
 poor combustion state, pulverized coal non-
 injection, unreduced molten material falling,
 and coke turning;
 wherein the combustion state index accord-
 ing to each of the tuyeres comprises at least
 one of a combustion state defect index, a
 pulverized coal noninjection index, an un-
 reduced molten material falling index, a
 coke turning index, a combustion state level
 index, a pulverized coal flow rate index, and
 a tuyere raceway index.

Patentansprüche

1. System (100) zur Bewertung von Betriebsbedingun-

gen eines Hochofens, umfassend:

eine Bilderfassungseinheit (110) zum Erfassen von Bilddaten gemäß jeder einer Vielzahl von Winddüsen (11), die in einem Hochofen bereitgestellt ist; 5
 eine Bildsammereinheit (120) zum Sammeln der Bilddaten, die gemäß jeder der Winddüsen (11) durch die Bilderfassungseinheit (110) erfasst wurden, 10
 eine Winddüsenverbrennungszustandsbestimmungseinheit (130) zum Einstufen von Verbrennungszuständen auf der Grundlage von künstlicher Intelligenz gemäß jeder der Winddüsen (11) unter Verwendung der Bilddaten gemäß jeder der Winddüsen, 15
 eine Winddüsenverbrennungszustandsindexerzeugungseinheit (140) zum Erzeugen eines Verbrennungszustandsindex gemäß jeder der Winddüsen (11) unter Verwendung des Ergebnisses des Einstufens der Verbrennungszustände gemäß jeder der Winddüsen durch die Winddüsenverbrennungszustandsbestimmungseinheit (130); und 20
 eine integrierte Bewertungseinheit (160) zum Erzeugen eines integrierten Verbrennungszustandsindex auf der Grundlage des Verbrennungszustandsindex gemäß jeder der Winddüsen, 25
dadurch gekennzeichnet, dass 30
 die Winddüsenverbrennungszustandsbestimmungseinheit (130) eine KI-basierte Bestimmungseinheit (131) zum Einstufen von Verbrennungszuständen gemäß jeder der Winddüsen (11) auf der Grundlage von Deep Learning unter Verwendung der Bilddaten gemäß jeder der Winddüsen umfasst; 35
 wobei die KI-basierte Bestimmungseinheit (131) die Verbrennungszustandseinstufung gemäß jeder der Winddüsen (11) auf der Grundlage eines Ergebnisses des Ansammelns eines Ergebnisses des Einstufens der Verbrennungszustände gemäß jeder der Winddüsen bestimmt, die auf der Grundlage von Deep Learning in zeitlicher Abfolge für einen vorbestimmten Zeitraum eingestuft werden; 40
 wobei der Zeitraum gemäß den Informationen über die abgelaufene Zeit von einem Zeitpunkt, zu dem die Winddüsenverbrennungszustandseinstufung zuerst detektiert wird, zu einem Zeitpunkt, zu dem die Winddüsenverbrennungszustandseinstufung in einen anderen Zustand übergeht, angepasst wird, 45
 wobei die Verbrennungszustandseinstufung einen normalen Verbrennungszustand, einen schlechten Verbrennungszustand, Nichteinspritzung von Kohlestaub, Herabfallen von nicht reduziertem geschmolzenem Material und Dre-

hen von Koks umfasst;

wobei der Verbrennungszustandsindex gemäß jeder der Winddüsen mindestens einen von einem Verbrennungszustandsmangelindex, einem Index für die Nichteinspritzung von Kohlestaub, einem Index für das Herabfallen von nicht reduziertem geschmolzenem Material, einem Index für das Drehen von Koks, einem Verbrennungszustandsgradindex, einem Kohlestaubdurchsatzindex und einem Winddüsenkanalindex umfasst.

2. System (100) zur Bewertung von Betriebsbedingungen eines Hochofens nach Anspruch 1, wobei die KI-basierte Bestimmungseinheit (131) die Verbrennungszustandseinstufung bestimmt, wenn eine beliebige Verbrennungszustandseinstufung mehr als eine vorbestimmte Anzahl von Malen während des Zeitraums auftritt.
3. System (100) zur Bewertung von Betriebsbedingungen eines Hochofens nach Anspruch 1, wobei die Winddüsenverbrennungszustandsbestimmungseinheit (130) ferner eine auf Bildverarbeitung basierende Bestimmungseinheit (132) zum Diagnostizieren einer Winddüseneinrichtung durch Bildverarbeitung an den Bilddaten gemäß jeder der Winddüsen und Bestimmen des Winddüsenverbrennungszustands umfasst.
4. System (100) zur Bewertung von Betriebsbedingungen eines Hochofens nach Anspruch 1, ferner umfassend eine Hochofenbedingungssteuereinheit (170) zum Durchführen mindestens eines von Kohlestaubespritzsteuerung, N2-Spülsteuerung und Hochofenbeschickungssteuerung auf der Grundlage des Verbrennungszustandsindex gemäß jeder der Winddüsen oder des integrierten Verbrennungszustandsindex.
5. Verfahren zum Bewerten von Betriebsbedingungen eines Hochofens, die folgenden Vorgänge umfassend:

Sammeln von Bilddaten gemäß einer Vielzahl von Winddüsen, die in einem Hochofen bereitgestellt ist (S510);
 Einstufen eines Verbrennungszustands gemäß jeder der Winddüsen auf der Grundlage von künstlicher Intelligenz unter Verwendung der Bilddaten gemäß jeder der Winddüsen (S520);
 Erzeugen eines Verbrennungszustandsindex gemäß jeder der Winddüsen unter Verwendung des Ergebnisses des Einstufens des Verbrennungszustands gemäß jeder der Winddüsen (S530); und
 Erzeugen eines integrierten Verbrennungszustandsindex auf der Grundlage des Verbren-

nungszustandsindex gemäß jeder der Windddüsen (S540),
wobei der Vorgang des Einstufens des Verbrennungszustands gemäß jeder der Windddüsen folgende Vorgänge umfasst:

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Einstufen des Verbrennungszustands gemäß jeder der Windddüsen auf der Grundlage von Deep Learning unter Verwendung der Bilddaten gemäß jeder der Windddüsen, Bestimmen einer Verbrennungszustandseinstufung gemäß jeder der Windddüsen auf der Grundlage eines Ergebnisses des Ansammelns des Ergebnisses des Einstufens des Verbrennungszustands gemäß jeder der Windddüsen, der auf der Grundlage von Deep Learning für einen vorbestimmten Zeitraum eingestuft wird, und Anpassen des Zeitraums gemäß den Informationen über die abgelaufene Zeit von einem Zeitpunkt, zu dem die Windddüsenverbrennungszustandseinstufung zuerst detektiert wird, zu einem Zeitpunkt, zu dem die Windddüsenverbrennungszustandseinstufung in einen anderen Zustand übergeht, wobei zum Zeitpunkt der ersten Durchführung, die zu dem Zeitpunkt beginnt, zu dem die Einstufung des Verbrennungszustands der entsprechenden Windddüse zuerst detektiert wird, die Windddüsenverbrennungszustandseinstufung durch Ansammeln der Ergebnisse bestimmt werden kann, die primär für einen Zeitraum eingestuft wurden, der von einem Benutzer eingestellt wurde, und wenn das Bestimmungsergebnis der Windddüsenverbrennungszustandseinstufung angesammelt ist, der Zeitraum gemäß den Informationen über die abgelaufene Zeit anhand der Zeitinformationen von dem Zeitpunkt, zu dem die Windddüsenverbrennungszustandseinstufung zuerst detektiert wird, zu dem Zeitpunkt, zu dem die Windddüsenverbrennungszustandseinstufung in einen anderen Zustand übergeht, angepasst wird, wobei die Verbrennungszustandseinstufung einen normalen Verbrennungszustand, einen schlechten Verbrennungszustand, Nichteinspritzung von Kohlestaub, Herabfallen von nicht reduziertem geschmolzenem Material und Drehen von Koks umfasst; wobei der Verbrennungszustandsindex gemäß jeder der Windddüsen mindestens einen von einem Verbrennungszustandsmangelindex, einem Index für die Nichteinspritzung von Kohlestaub, einem Index für das Herabfallen von nicht reduziertem ge-

schmolzenem Material, einem Index für das Drehen von Koks, einem Verbrennungszustandsgradindex, einem Kohlestaubdurchsatzindex und einem Windddüsenkanalindex umfasst.

Revendications

1. Système (100) d'évaluation de conditions opérationnelles d'un haut-fourneau, comprenant :

une unité de capture d'image (110) pour la capture de données d'image selon chacune d'une pluralité de tuyères (11) prévues dans un haut-fourneau ;
une unité de collecte d'image (120) pour la collecte des données d'image capturées selon chacune des tuyères (11) par l'unité de capture d'image (110) ;
une unité de détermination d'état de combustion de tuyère (130) pour la classification, sur la base de l'intelligence artificielle, d'états de combustion selon chacune des tuyères (11), en utilisant les données d'image selon chacune des tuyères ;
une unité de génération d'indice d'état de combustion de tuyère (140) pour la génération d'un indice d'état de combustion selon chacune des tuyères (11) en utilisant le résultat de classification des états de combustion selon chacune des tuyères par l'unité de détermination d'état de combustion de tuyère (130) ; et
une unité d'évaluation intégrée (160) pour la génération d'un indice d'état de combustion intégré sur la base de l'indice d'état de combustion selon chacune des tuyères,
caractérisé en ce que,
l'unité de détermination d'état de combustion de tuyère (130) comprend une unité de détermination par IA (131) pour la classification d'états de combustion selon chacune des tuyères (11) par apprentissage profond à l'aide des données d'image selon chacune des tuyères ;
dans lequel l'unité de détermination par IA (131) détermine la classification d'état de combustion selon chacune des tuyères (11) d'après un résultat d'accumulation d'un résultat de classification des états de combustion selon chacune des tuyères classifiés par apprentissage profond en séries temporelles pendant une période prédéterminée ;
dans lequel la période est ajustée selon des informations de temps écoulé à partir d'un moment auquel la classification d'état de combustion de tuyère est d'abord détectée jusqu'à un moment auquel la classification d'état de combustion de tuyère passe à un autre état ;

- dans lequel la classification d'état de combustion comprend un état de combustion normale, un état de combustion médiocre, une non-injection de charbon pulvérisé, une chute de matière fondue non réduite et une transformation en coke ;
 dans lequel l'indice d'état de combustion selon chacune des tuyères comprend au moins l'un parmi un indice de défaut d'état de combustion, un indice de non-injection de charbon pulvérisé, un indice de chute de matière fondue non réduite, un indice de transformation en coke, un indice de niveau d'état de combustion, un indice de débit de charbon pulvérisé et un indice de chemin de roulement de tuyère. 5 10 15
2. Système (100) d'évaluation de conditions opérationnelles d'un haut-fourneau selon la revendication 1, dans lequel l'unité de détermination par IA (131) détermine la classification d'état de combustion si une quelconque classification d'état de combustion se produit plus d'un nombre de fois prédéterminé pendant la période. 20
3. Système (100) d'évaluation de conditions opérationnelles d'un haut-fourneau selon la revendication 1, dans lequel l'unité de détermination d'état de combustion de tuyère (130) comprend en outre une unité de détermination par traitement d'image (132) pour le diagnostic d'une installation de tuyères par traitement d'image sur les données d'image selon chacune des tuyères et la détermination de l'état de combustion de tuyère. 25 30
4. Système (100) d'évaluation de conditions opérationnelles d'un haut-fourneau selon la revendication 1, comprenant en outre une unité de commande de condition de haut-fourneau (170) pour la réalisation d'au moins l'une parmi une commande d'injection de charbon pulvérisé, une commande de purge de N₂ et une commande de charge de haut-fourneau, d'après l'indice d'état de combustion selon chacune des tuyères ou l'indice d'état de combustion intégré. 35 40
5. Procédé d'évaluation de conditions opérationnelles d'un haut-fourneau comprenant des opérations de : 45
- collecte de données d'image selon une pluralité de tuyères prévues dans un haut-fourneau (S510) ; 50
 - classification d'un état de combustion selon chacune des tuyères par intelligence artificielle à l'aide des données d'image selon chacune des tuyères (S520) ;
 - génération d'un indice d'état de combustion selon chacune des tuyères à l'aide du résultat de classification de l'état de combustion selon chacune des tuyères (S530) ; et 55

génération d'un indice d'état de combustion intégré d'après l'indice d'état de combustion selon chacune des tuyères (S540),
 dans lequel l'opération de classification de l'état de combustion selon chacune des tuyères comprend des opérations de :

classification de l'état de combustion selon chacune des tuyères par apprentissage profond à l'aide de données d'image selon chacune des tuyères ;
 détermination d'une classification d'état de combustion selon chacune des tuyères d'après un résultat d'accumulation du résultat de classification de l'état de combustion selon chacune des tuyères classifié par l'apprentissage profond pendant une période prédéterminée ; et
 ajustement de la période selon des informations de temps écoulé à partir d'un moment auquel la classification d'état de combustion de tuyère est d'abord détectée jusqu'à un moment auquel la classification d'état de combustion de tuyère passe à un autre état ;
 dans lequel, au moment de la réalisation initiale, le démarrage à partir du moment auquel la classification de l'état de combustion de la tuyère correspondante est d'abord détectée, la classification d'état de combustion de tuyère peut être déterminée par l'accumulation des résultats principalement classifiés pendant une période fixée par un utilisateur et lorsque le résultat de détermination de la classification d'état de combustion de tuyère est accumulé, la période est ajustée selon les informations de temps écoulé à partir des informations de temps à partir du moment auquel la classification d'état de combustion de tuyère est d'abord détectée jusqu'au moment auquel la classification d'état de combustion de tuyère passe à un autre état ;
 dans lequel la classification d'état de combustion comprend un état de combustion normale, un état de combustion médiocre, une non-injection de charbon pulvérisé, une chute de matière fondue non réduite et une transformation en coke ;
 dans lequel l'indice d'état de combustion selon chacune des tuyères comprend au moins l'un parmi un indice de défaut d'état de combustion, un indice de non-injection de charbon pulvérisé, un indice de chute de matière fondue non réduite, un indice de transformation en coke, un indice de niveau d'état de combustion, un indice de débit de charbon pulvérisé et un indice de chemin

de roulement de tuyère.

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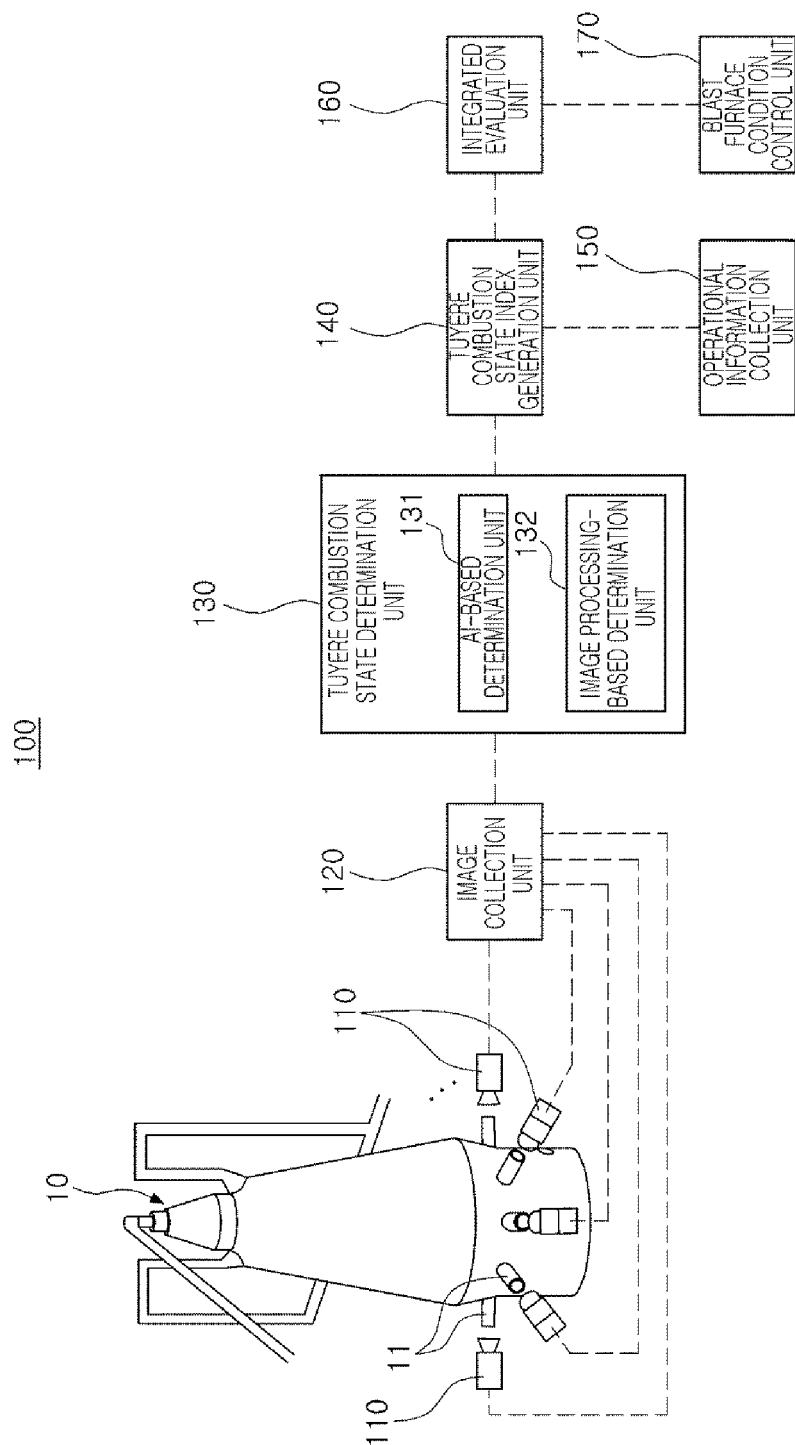
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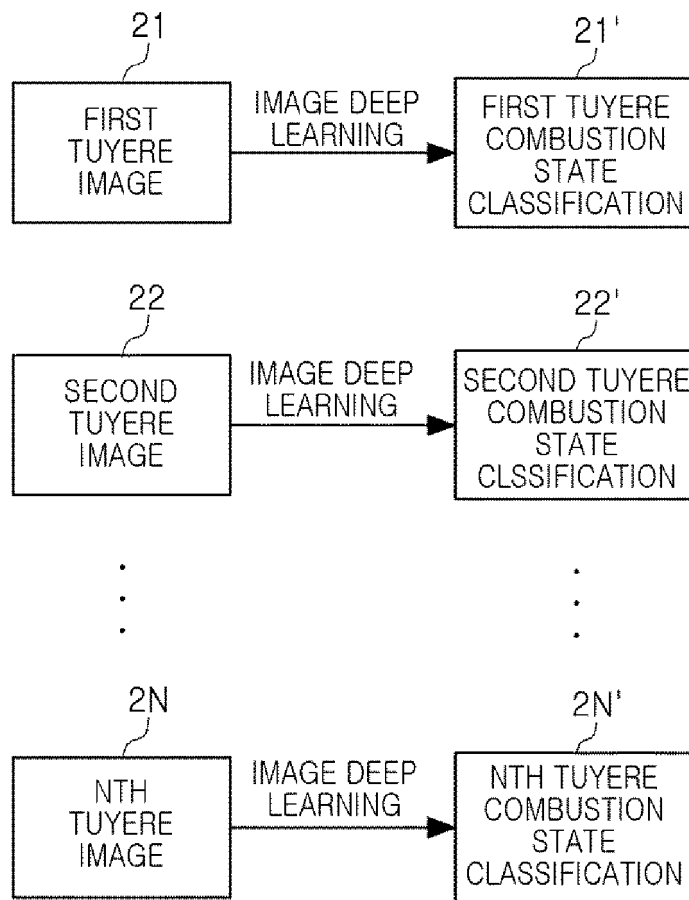
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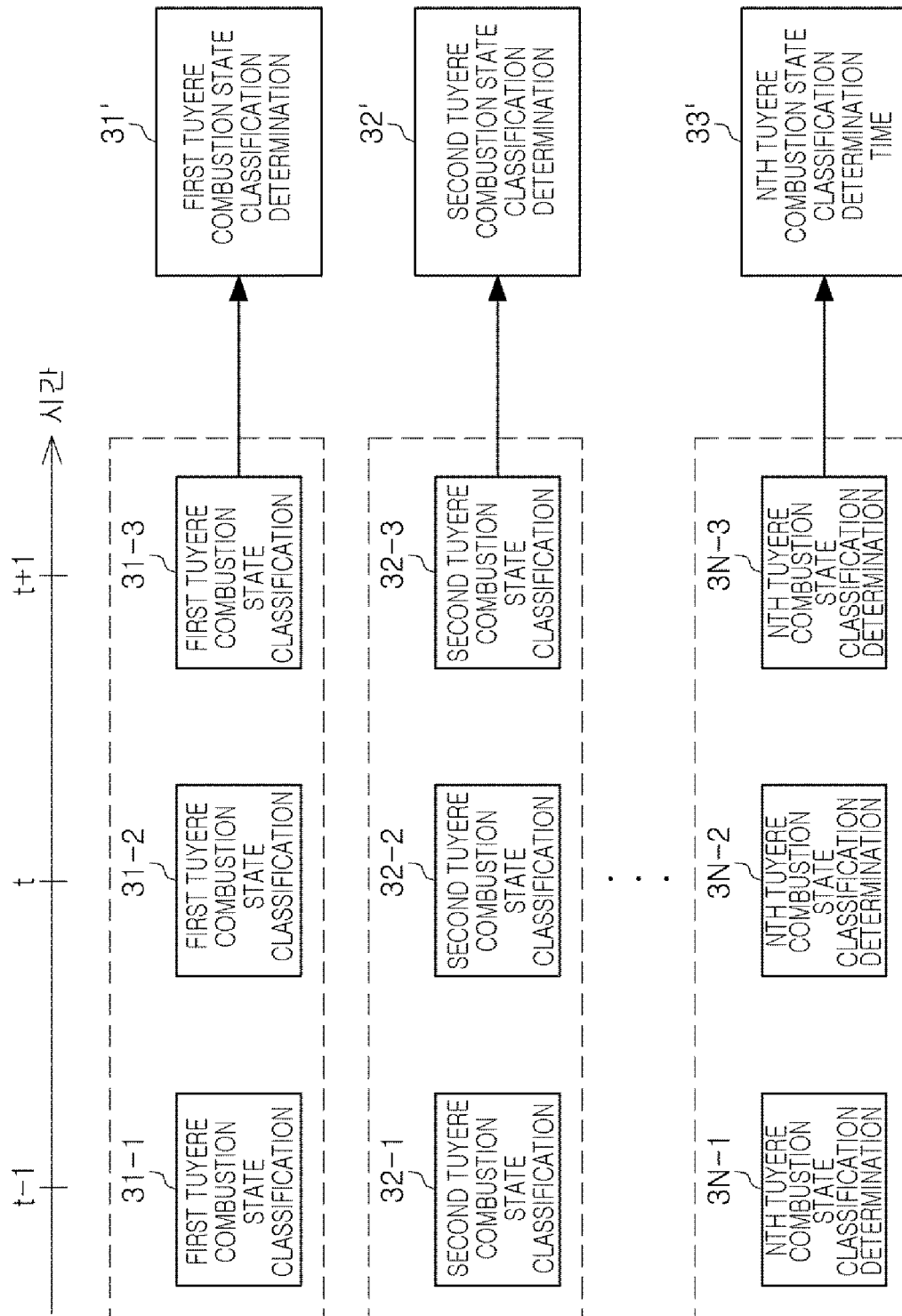
【FIG. 1】



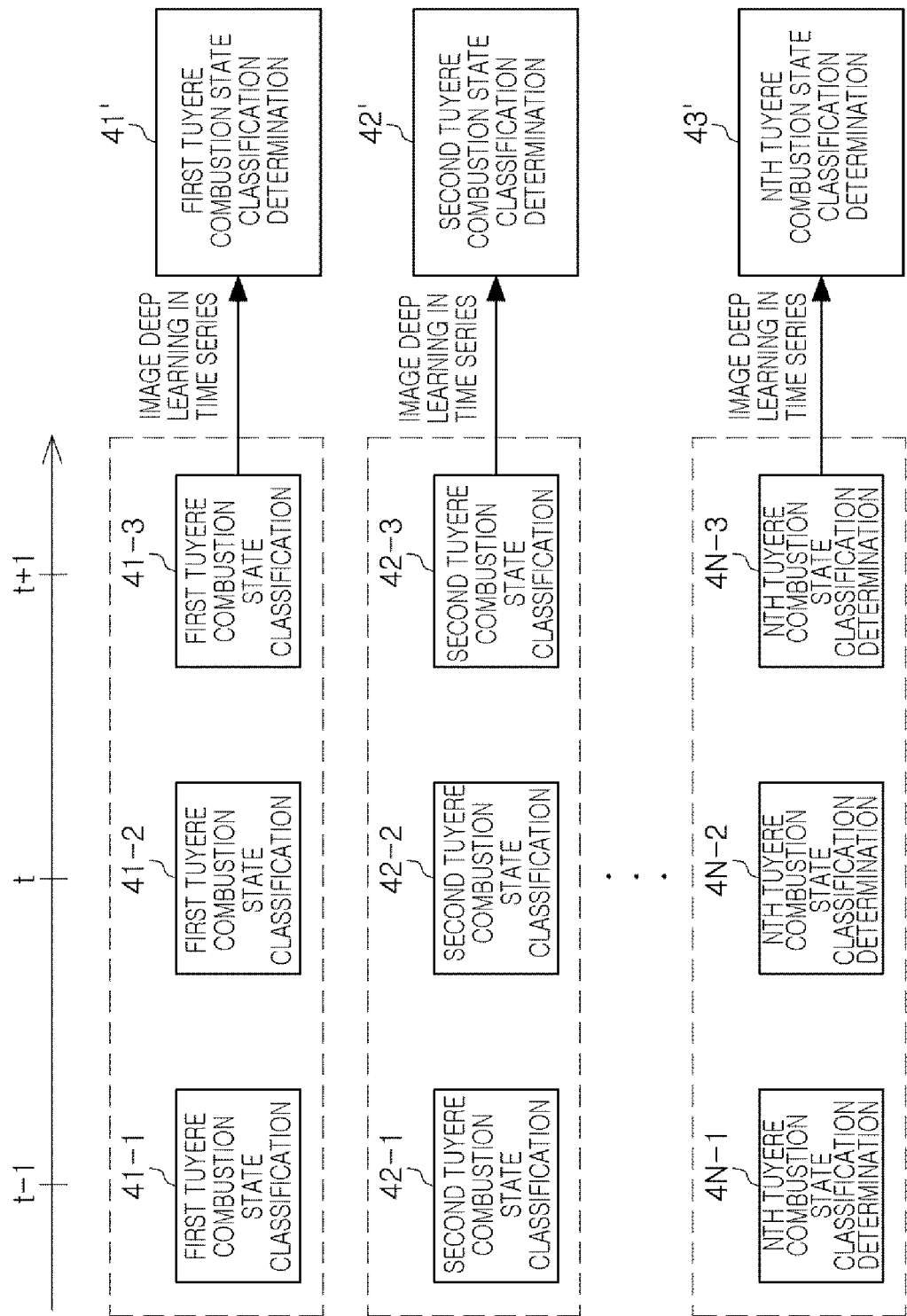
【FIG. 2】



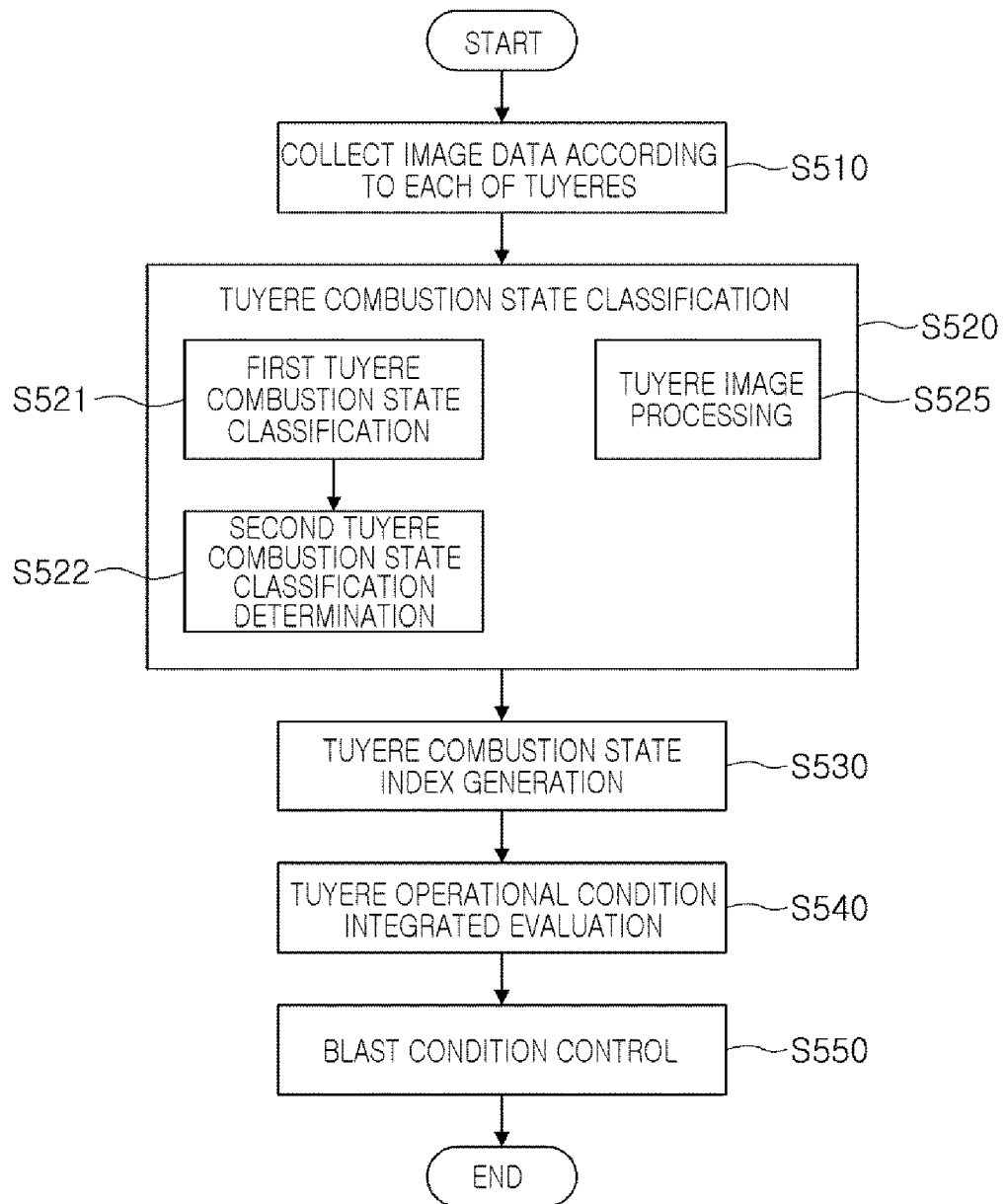
【FIG. 3】



【FIG. 4】



【FIG. 5】



REFERENCES CITED IN THE DESCRIPTION

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