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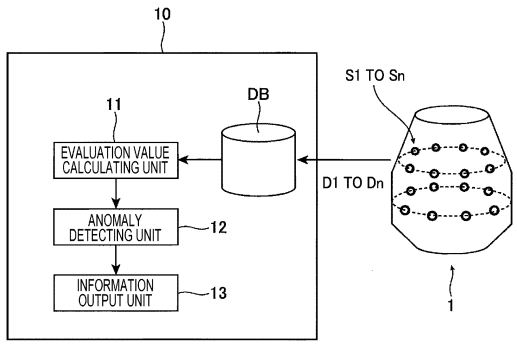
(54) **BLAST FURNACE IRREGULARITY ASSESSMENT DEVICE, BLAST FURNACE IRREGULARITY ASSESSMENT METHOD, BLAST FURNACE OPERATION METHOD, AND MOLTEN PIG IRON PRODUCTION METHOD**

(57) [Object] An object is to provide an anomaly determining apparatus and method capable of detecting not only a state anomaly, but also a premonitory sign of state anomaly in a blast furnace.

[Solution] An anomaly determining apparatus 10 detects an anomaly in a blast furnace 1 using a plurality of sensors S1 to Sn installed at different positions of the blast furnace 1. The anomaly determining apparatus 10 includes an evaluation value calculating unit 11 configured to calculate an evaluation value from a plurality of pieces of measurement data D1 to Dn detected by the plurality of sensors S1 to Sn, and an anomaly detecting unit 12 configured to detect an anomaly in the blast furnace 1 on the basis of the evaluation value EV calculated by the evaluation value calculating unit 11 using an anomaly threshold EVref1 and an anomaly premonitory sign threshold EVref2 smaller than the anomaly threshold EVref1. If the evaluation value EV is greater than the anomaly threshold EVref1, the anomaly detecting unit 12 determines that there is an anomaly, and if a period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 continues for a set period PT or longer, the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a blast furnace anomaly determining apparatus and a blast furnace anomaly determining method that detect an anomaly, such as hanging or gas-channeling, associated with poor gas permeability in a blast furnace, a blast furnace operating method using the blast furnace anomaly determining apparatus, and a hot metal producing method.

Background Art

[0002] In a blast furnace for producing pig iron, iron ore and coke, which are raw materials, are typically alternately supplied through the furnace top and charged in ore and coke layers. The flow of gas in the furnace is controlled by adjusting the distribution of the ore and coke layers after charging in the furnace.

[0003] If deterioration of gas permeability in the blast furnace obstructs the smooth flow of gas in the furnace, there may be the occurrence of a furnace condition anomaly. The furnace condition anomaly refers to a state that significantly deviates from a steady state. Examples of the furnace condition anomaly are (1) to (3) below:

(1) "hanging" meaning that sequential descent of ore and coke from the upper part of the furnace is stopped;
(2) "slipping" meaning that ore and coke at rest suddenly begin to descend; and
(3) "gas-channeling" meaning that a high-temperature gas supplied from the lower part of the furnace is abruptly blown out toward the upper part of the furnace.

[0004] For example, gas-channeling causes a problem, such as damage to facilities at the furnace top or reduction of furnace heat. To prevent the occurrence of furnace condition anomalies, it is important to quickly and accurately recognize the gas permeability state and always maintain good conditions in the furnace.

[0005] As an index indicating gas permeability in the furnace, gas permeability resistance has been conventionally used, which is calculated for example from a difference between furnace top pressure and blast pressure. For example, Patent Literature 1 proposes a technique that detects a blast furnace anomaly from shaft pressure data on the basis of principal component analysis. The technique disclosed in Patent Literature 1 involves calculating, for example, a Q statistic from a plurality of shaft pressures at different positions of the blast furnace using principal component analysis, and performing an anomaly determination on the basis of the Q statistic.

Citation List

Patent Literature

[0006] PTL 1: Japanese Unexamined Patent Application Publication No. 2017-128805

Summary of Invention

Technical Problem

[0007] Raw materials fed through the furnace top descend over a long time (e.g., about eight hours) to reach the lower part of the furnace, and conditions in the furnace slowly change accordingly. This means that the gas permeability state may deteriorate gradually, if any, not abruptly. Since such slow deterioration of a state may also cause future troubles, it is desirable to take appropriate measures, such as blast volume reduction, at an early stage.

[0008] However, when an anomaly determination is made using only one threshold as in Patent Literature 1, it is difficult to detect a gradually deteriorating state. Also, when the threshold for anomaly determination is lowered to perform earlier anomaly detection, a frequent occurrence of overdetection makes it difficult to perform the original function of the anomaly detection.

[0009] Accordingly, the present invention aims to provide an anomaly determining apparatus and method capable of detecting not only a state anomaly, but also a premonitory sign of state anomaly in a blast furnace.

Solution to Problem

[0010] The present invention provides the following features to solve the problems described above:

[1] A blast furnace anomaly determining apparatus that detects an anomaly in a blast furnace using a plurality of sensors installed at different positions of the blast furnace, the anomaly determining apparatus including an evaluation value calculating unit configured to calculate an evaluation value from a plurality of pieces of measurement data detected by the plurality of sensors; and an anomaly detecting unit configured to detect an anomaly in the blast furnace on the basis of the evaluation value calculated by the evaluation value calculating unit using an anomaly threshold and an anomaly premonitory sign threshold smaller than the anomaly threshold, wherein if the evaluation value is greater than the anomaly threshold, the anomaly detecting unit determines that there is an anomaly, and if a period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to a set period, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

[2] The blast furnace anomaly determining apparatus according to [1], wherein the anomaly detecting unit determines, every predetermined determination period, whether a cumulative period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to the set period, and if the cumulative period is longer than or equal to the set period, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

[3] The blast furnace anomaly determining apparatus according to [1] or [2], wherein if a time integral of the evaluation value is greater than an integral threshold, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

[4] The blast furnace anomaly determining apparatus according to any one of [1] to [3], wherein the evaluation value calculating unit performs principal component analysis on the plurality of pieces of measurement data to calculate a Q statistic or a T^2 statistic, and calculates the evaluation value on the basis of the calculated Q statistic or T^2 statistic.

[5] The blast furnace anomaly determining apparatus according to any one of [1] to [4], wherein the plurality of sensors are constituted by shaft pressure sensors installed at different positions in height direction and different positions in circumferential direction of the blast furnace.

[6] A blast furnace anomaly determining method for detecting an anomaly in a blast furnace using a plurality of sensors installed at different positions of the blast furnace, the anomaly determining method including an evaluation value calculating step of calculating an evaluation value from a plurality of pieces of measurement data detected by the plurality of sensors; and an anomaly detecting step of detecting an anomaly in the blast furnace on the basis of the calculated evaluation value using an anomaly threshold and an anomaly premonitory sign threshold smaller than the anomaly threshold, wherein if the evaluation value is greater than the anomaly threshold, the anomaly detecting step determines that there is an anomaly, and if a period during which the evaluation value is greater than the anomaly threshold is longer than or equal to a set period, the anomaly detecting step determines that there is a premonitory sign of anomaly.

[7] The blast furnace anomaly determining method according to [6], wherein the anomaly premonitory sign threshold is determined using an evaluation value of the plurality of pieces of measurement data calculated when variation of some pressure values of the plurality of pieces of measurement data during usual operation exceeds a predetermined range of variation in pressure values in a normal state.

[8] A blast furnace operating method including operating a blast furnace while making a determination of an anomaly in the blast furnace using the blast furnace anomaly determining apparatus according to any one of [1] to [5].

[9] A hot metal producing method including producing hot metal with the blast furnace operating method according to [8].

Advantageous Effects of Invention

[0011] By using the fact that the occurrence of an anomaly is preceded by a premonitory sign of the anomaly, the anomaly determining apparatus and method according to the present invention not only detect the occurrence of an anomaly when the evaluation value exceeds the anomaly threshold, but also detect a premonitory sign of anomaly when a period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to the set period. This makes it possible to take preventive measures, such as blast volume reduction, against anomalies at an early stage to prevent operational troubles.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a block diagram illustrating a preferred embodiment of an anomaly determining apparatus according to the present invention.

[Fig. 2] Fig. 2 is a graph illustrating two pieces of measurement data measured by different sensors in Fig. 1.

[Fig. 3] Fig. 3 is another graph illustrating two pieces of measurement data measured by different sensors in Fig. 1.

[Fig. 4] Fig. 4 is a graph showing an exemplary evaluation value calculated by an evaluation value calculating unit illustrated in Fig. 1.

[Fig. 5] Fig. 5 is a graph showing how a premonitory sign of anomaly is detected by an anomaly detecting unit illustrated in Fig. 1.

[Fig. 6] Fig. 6 is a graph showing how the evaluation value is time-integrated by the anomaly detecting unit illustrated in Fig. 1.

[Fig. 7] Fig. 7 is a flowchart illustrating a preferred embodiment of a blast furnace anomaly determining method according to the present invention.

Description of Embodiments

[0013] Embodiments of the present invention will now be described. Fig. 1 is a block diagram illustrating a preferred embodiment of a blast furnace anomaly determining apparatus according to the present invention. A configuration of an anomaly determining apparatus 10 illustrated in Fig. 1 is implemented on a computer by executing a program stored in the computer. The blast furnace anomaly determining apparatus 10 illustrated in Fig. 1 is configured to detect an anomaly in the blast furnace 1 using a plurality of sensors S1 to Sn installed at different positions of the blast furnace.

[0014] For example, the plurality of sensors S1 to Sn are a plurality of (e.g., 30) shaft pressure sensors installed at different positions in the height direction and the circumferential direction of the blast furnace 1. A plurality of pieces of measurement data D1 to Dn measured by the respective sensors S1 to Sn are stored in a database DB of the anomaly determining apparatus 10. The blast furnace anomaly determining apparatus 10 detects an anomaly and a premonitory sign of anomaly in the blast furnace on the basis of the plurality of pieces of measurement data D1 to Dn.

[0015] The blast furnace anomaly determining apparatus 10 includes an evaluation value calculating unit 11, an anomaly detecting unit 12, and an information output unit 13. The evaluation value calculating unit 11 calculates an evaluation value EV from the plurality of pieces of measurement data D1 to Dn detected by the plurality of sensors S1 to Sn. For example, the evaluation value calculating unit 11 calculates the evaluation value EV by applying principal component analysis to the plurality of pieces of measurement data D1 to Dn. The principal component analysis (PCA) refers to a mathematical process which involves transforming a plurality of data groups through dimensionality reduction into variables reflecting features of the original data, while reducing loss of information content of the original data groups. Instead of monitoring all the data groups, a few variables produced by dimensionality reduction using principal component analysis are monitored, so that the monitoring of conditions in the furnace is simplified.

[0016] Fig. 2 and Fig. 3 are graphs illustrating two pieces of measurement data measured by different sensors in Fig. 1. During normal operation in the blast furnace 1, the measurement data D1 and D2 have a tendency to change in a synchronized manner within a predetermined range of signal values as shown in Fig. 2. Being synchronized means that operational measurement data (variables) behave in a coordinated manner with respect to the passage of time or the operational actions in the process. During normal operation, as illustrated in Fig. 3, the measurement data D1 and D2 are plotted around a straight line representing synchronization (measurement data D1 = measurement data D2) within a predetermined range of signal values.

[0017] In the event of an anomaly in the blast furnace 1, the different measurement data D1 and D2 have a tendency to fall outside the predetermined range of signal values while being in synchronization with each other, or the measurement data D1 and D2 have a tendency to go out of synchronization. That is, in Fig. 3, in the event of an anomaly of gas permeability in the blast furnace 1, the measurement data D1 and D2 are plotted outside the predetermined range of signal values, or plotted away from the straight line representing synchronization. In the shaft pressure data of the blast furnace 1, first principal component values with the greatest variance in the principal component analysis reflect the components of synchronous movement of each shaft pressure during stable operation of the blast furnace 1, whereas the second and subsequent principal components in the principal component analysis reflect components outside the stable period.

[0018] Although only the two pieces of measurement data D1 and D2 are shown for ease of explanation, the plurality of pieces of measurement data D1 to Dn have the same tendency. Therefore, the evaluation value calculating unit 11 determines one Q statistic or T^2 statistic from n pieces of measurement data. The T^2 statistic is an index indicating whether a signal is within a predetermined variation range. The Q statistic is an index orthogonal to the T^2 statistic and representing asynchronousness. The Q statistic or T^2 statistic can be calculated using a known technique. Although an example of using second principal component values is shown, third or subsequent principal component values may be used if they well represent an anomalous phenomenon.

[0019] The evaluation value calculating unit 11 stores therein in advance the maximum value of Q statistics of the second principal component calculated using measurement data obtained during normal operation. The normal operation section includes data of stability limit within which the operation is determined to be normal. Determining the maximum value of the second principal component for the normal operation section means determining the range of variation of measurement data obtained during normal operation and the maximum deviation from the normal operation range (i.e., stability limit value). The evaluation value calculating unit 11 determines, as the evaluation value EV, a Q statistic index obtained by dividing the Q statistic calculated from the measurement data D1 to Dn by the maximum value stored.

[0020] Although the evaluation value calculating unit 11 calculates the evaluation value EV using Q statistics in the example described above, the evaluation value calculating unit 11 may calculate the evaluation value EV using T^2 statistics. In this case, again, the evaluation value calculating unit 11 stores therein in advance the maximum value of T^2 statistics calculated using measurement data obtained during normal operation. The evaluation value calculating unit 11 calculates a T^2 statistic from measurement data and determines, as the evaluation value EV, a T^2 statistic index obtained by dividing the calculated T^2 statistic by the maximum value stored.

[0021] Fig. 4 is a graph showing an example of the evaluation value EV calculated by the evaluation value calculating unit illustrated in Fig. 1. The anomaly detecting unit 12 detects an anomaly in the blast furnace 1 on the basis of the evaluation value EV calculated by the evaluation value calculating unit 11. The anomaly detecting unit 12 stores therein an anomaly threshold EVref1 and an anomaly premonitory sign threshold EVref2 smaller than the anomaly threshold EVref1. If the evaluation value EV is greater than the anomaly threshold EVref1, the anomaly detecting unit 12 determines that there is an anomaly. If a period during which the evaluation value EV is smaller than or equal to the anomaly threshold EVref1 and greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to a set period PT, the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly. If the evaluation value EV is the Q statistic index, the anomaly threshold EVref1 is set to fall within a range of, for example, 0.5 to 1.0 and the anomaly premonitory sign threshold EVref2 is set to, for example, 0.5 or below. EVref1 may be determined, for example, in accordance with the evaluation value EV obtained immediately before (several minutes before) the actual occurrence of gas-channeling in the past.

[0022] The difference between an anomaly and a premonitory sign of anomaly in the blast furnace 1 will now be described. A state where a premonitory sign of anomaly occurs refers to a state where local minor variation of pressure occurs in the blast furnace 1. The pressure variation is caused, for example, by local irregularities in the raw material layer, accumulation of fine particles such as coke powder, or local variation in stock movement (descent of raw materials).

[0023] In the blast furnace 1, the pressure variation propagates from the origin of minor pressure variation in various directions inside the furnace, and this may result in the occurrence of pressure variation at other locations. For example, there is a phenomenon in which even local minor irregularities in the raw materials change the flow of passing gas in the blast furnace 1 and change the temperature rise and reduction of the raw materials. In the blast furnace 1, where the passing gas flows upward from the lower part, the minor irregularities in the raw materials propagate while affecting the state of the neighborhood and the upper part. At the same time, as the raw materials descend, the minor irregularities in the raw materials propagate while affecting the state of the lower part. The local minor irregularities in the raw materials thus propagate while affecting the upper and lower parts, and result in major irregularities (anomaly).

[0024] Even local pressure variation is considered an anomaly if the level of pressure variation is significant. For example, when pressure at a specific position in the circumferential direction gradually increases (i.e., the evaluation value EV gradually increases) as stock movement deteriorates and then the pressure is released, only a group of a plurality of sensors set in the height direction in the same circumferential direction are significantly influenced and reflect an anomaly.

[0025] As described above, the occurrence of an anomaly in the blast furnace 1 is preceded by the occurrence of minor pressure variation, which is a premonitory sign of anomaly. This means that if the minor pressure variation (premonitory sign) is successfully detected, the occurrence of an anomaly can be predicted.

[0026] The anomaly premonitory sign threshold EVref2 for detecting the occurrence of local minor pressure variation as a premonitory sign is defined. The anomaly premonitory sign threshold EVref2 may be determined using the evaluation value EV at the time of occurrence of a premonitory sign in the operation of the blast furnace 1 where the premonitory sign had been detected among the operations of the blast furnace 1 where an anomaly has occurred.

[0027] The anomaly premonitory sign threshold EVref2 may be determined in the following manner. When local pressure variation propagates in the blast furnace 1, the variation of local pressure probably takes place in an area of about several meters by several meters in contact with the furnace body. In the example illustrated in Fig. 1, about four pressure gages are influenced by this variation. Therefore, the anomaly premonitory sign threshold EVref2 may be determined using the evaluation value EV obtained when variation in the pressure values of the influenced pressure gages exceeds 2σ, where σ is the standard deviation of variation in the pressure values during usual operation (in a normal state).

[0028] The anomaly detecting unit 12 determines, every predetermined determination period (e.g., every 45 minutes), whether a cumulative period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to the set period PT (e.g., 40 minutes). Then, if the cumulative period does not become greater than or equal to the set period PT within the determination period, the anomaly detecting unit 12 resets the counted period and starts measurement of another period. This is because since the evaluation value EV may accidentally drop for a short time, if the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly only when the evaluation value EV continuously exceeds the anomaly premonitory sign threshold EVref2 for longer than or equal to the set period PT, the anomaly detecting unit 12 may fail to detect a premonitory sign of anomaly. Therefore, even when the period during which the evaluation value EV is greater than or equal to the anomaly premonitory sign threshold EVref2 is not continuous, the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly as long as the cumulative period becomes greater than or equal to the set period PT within the predetermined determination period.

[0029] A set period PT is desirably set to a period shorter than the period between the occurrence of the premonitory sign and the occurrence of the anomaly in an operation where a premonitory sign has been identified before the occurrence of an anomaly in an operation of the blast furnace 1. This makes it possible to perform, for example, blast volume reduction at an earlier stage and prevent the occurrence of an anomaly.

[0030] Since anomalies accumulated in a low-level state may lead to an anomaly, such as gas-channeling, it is desirable not to make the set period PT too long. To take preventive measures well in advance of the occurrence of a serious anomaly, the predetermined determination period is set to 45 minutes and the set period PT is set to 40 in the present embodiment. This period is set, by taking into account the stock movement rate and the heating rate, in such a way that it is possible to reduce the risk of an anomaly, such as gas-channeling, resulting from propagation and spreading of a local anomaly region. The stock movement rate in the blast furnace 1 is about 4 m/h. To prevent the stock movement from causing the anomaly region to spread more than 3 m in the height direction, the determination period is set to 45 minutes.

[0031] Depending on the type of the blast furnace 1 or its operation mode, an anomaly may occur after a brief premonitory sign. It is preferable in this case to make the set period PT shorter. For example, if continuous stock movement is obstructed by wear of bricks inside the furnace body, an anomaly may occur after a brief premonitory sign. In this case, it is preferable to make the predetermined determination period and the set period PT shorter. Note that even in the case of making the predetermined determination period and the set period PT shorter, it is preferable, for prevention of erroneous detection, that the predetermined determination period be set to 10 minutes or longer and the set period PT be set to 8 minutes or longer.

[0032] Fig. 5 is a graph showing how a premonitory sign of anomaly is detected by the anomaly detecting unit illustrated in Fig. 1. As illustrated in Fig. 5(A), the anomaly detecting unit 12 determines, every minute, whether the evaluation value EV exceeds the anomaly premonitory sign threshold EVref2 and counts the number of determinations. The count value is reset every determination period (e.g., 45 minutes). Then, when the count value of the counter reaches a set number of times (e.g., 40 times = set period PT), the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly as illustrated in Fig. 5(B).

[0033] Instead of performing the threshold processing, the anomaly detecting unit 12 may determine, when a time integral I of the evaluation value EV exceeds an integral threshold Iref, that there is a premonitory sign of anomaly. Fig. 6 is a graph showing how the evaluation value is time-integrated by the anomaly detecting unit illustrated in Fig. 1. For example, the time to reach the anomaly threshold EVref1 when the condition of "evaluation value EV = 0.8" continues is shorter than that when the condition of "evaluation value EV = 0.6" continues. Accordingly, the anomaly detecting unit 12 determines that there is a premonitory sign of anomaly when the integral I exceeds the integral threshold Iref in such a way that a premonitory sign of anomaly is output at an early stage when the evaluation value EV continues to be large.

[0034] Performing time integration means that the set period PT serving as a reference is changed in accordance with the evaluation value EV. A determination made when "integral threshold Iref = set period PT $\times$ anomaly premonitory sign threshold EVref2" is the same as the determination made when the period during which the evaluation value EV exceeds the anomaly premonitory sign threshold EVref2 is the set period PT.

[0035] The information output unit 13 illustrated in Fig. 1 may be constituted, for example, by a display device or a speaker. When a premonitory sign of anomaly is detected, the information output unit 13 outputs the corresponding information as a notification to the operator. Upon being notified that a premonitory sign of anomaly has been detected, the operator adjusts the conditions of the blast furnace operation, for example, by reducing the volume of blast supplied into the blast furnace or by stopping the supply of blast so as to prevent the occurrence of anomalous phenomena. It is thus possible to prevent the occurrence of anomalous phenomena or furnace condition anomalies, such as hanging, slipping, and gas-channeling, caused by poor gas permeability. When the anomaly detecting unit 12 detects an anomaly or a premonitory sign of anomaly, a control device (not shown) may automatically reduce the blast volume or stop the supply of blast.

[0036] Fig. 7 is a flowchart illustrating a preferred embodiment of an anomaly determining method according to the present invention. An anomaly determining method will be described with reference to Fig. 7. First, the measurement data D1 to Dn are acquired from the plurality of sensors S1 to Sn (step ST1) and the evaluation value calculating unit 11 calculates the evaluation value EV (evaluation value calculating step, step ST2). Then, the anomaly detecting unit 12 determines whether the evaluation value EV is greater than the anomaly threshold EVref1 (anomaly detecting step, step ST3).

[0037] If the evaluation value EV is greater than the anomaly threshold EVref1 (YES in step ST3), the anomaly detecting unit 12 determines that an anomaly occurs in the blast furnace, and the information output unit 13 outputs an alarm (step ST4). If the evaluation value EV is smaller than or equal to the anomaly threshold EVref1 (NO in step ST3), a further determination is made as to whether a period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 exceeds the set period PT (anomaly detecting step, step ST5). Alternatively, a determination as to whether the time integral I of the evaluation value EV is greater than the integral threshold may be made in step ST5.

[0038] If the period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 reaches the set period PT (YES in step ST5), a notification indicating that there is a premonitory sign of anomaly is output (step ST6). If the period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is shorter than the set period PT, the anomaly detecting unit 12 determines that there is no premonitory sign of anomaly (NO in step ST5) and monitoring for anomalies continues (steps ST1 to ST5).

[0039] By using the fact that the occurrence of an anomaly is preceded by a premonitory sign of anomaly, the embodiment described above detects the occurrence of an anomaly when the evaluation value EV exceeds the anomaly threshold EVref1. It is thus possible to carry out the operation of the blast furnace while making a determination of an anomaly in the blast furnace, and to produce hot metal by carrying out the operation. The present embodiment not only detects an anomaly, but also detects a premonitory sign of anomaly when the period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to the set period PT. Thus, since preventive measures, such as blast volume reduction, against anomalies can be taken at an early stage, it is possible to prevent operational troubles.

[0040] As described above, in the event of an anomaly exceeding the threshold EVref1, gas-channeling occurs and a bleeder valve at the furnace top is opened to release pressure. This allows the evaluation value EV to return to a normal value. In the event of gas-channeling, however, the resulting increase in heat loss may reduce furnace heat or damage the raw material layer. To prevent such a negative impact on the blast furnace, it is desirable to detect a premonitory sign of anomaly before the occurrence of an anomaly. Since the evaluation value EV has a tendency to become greater than that in a steady state, the anomaly premonitory sign threshold EVref2 lower than the anomaly threshold EVref1 is used to detect a premonitory sign of anomaly.

[0041] On the other hand, even when minor irregularities in the furnace slightly affect gas permeability, a possible occurrence of minor gas-channeling may allow the evaluation value EV to return to a normal value without the need for taking any measures, such as blast volume reduction. With the threshold processing alone, there may be cases where there is no need to output an alarm for example to an operator as a premonitory sign of anomaly. However, if minor irregularities in the furnace, such as that described above, are not followed by the occurrence of minor gas-channeling, a gradual deterioration of furnace conditions occurs and causes a gradual increase in the evaluation value EV. By using this, the anomaly detecting unit 12 detects a premonitory sign of anomaly when the cumulative period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to the set period PT. A premonitory sign of anomaly can thus be accurately detected without erroneous detection.

[0042] In particular, the anomaly detecting unit 12 determines a premonitory sign of anomaly by determining whether, in the predetermined determination period (e.g., 45 minutes), the cumulative period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to the set period PT (e.g., 40 minutes). Therefore, even if the evaluation value EV temporarily drops below the anomaly premonitory sign threshold EVref2, the anomaly detecting unit 12 can be prevented from erroneously determining that there is no premonitory sign of anomaly in the case when there is actually a premonitory sign of anomaly. Conversely, even if the evaluation value EV temporarily becomes greater than or equal to the anomaly premonitory sign threshold EVref2, the anomaly detecting unit 12 can be prevented from erroneously determining that there is a premonitory sign of anomaly in the case when there is actually no premonitory sign of anomaly. A more accurate detection of a premonitory sign of anomaly is thus achieved.

[0043] The anomaly detecting unit 12 may determine that there is a premonitory sign of anomaly when the time integral I of the evaluation value EV is greater than the integral threshold Iref. Thus, the period of time before determining that there is a premonitory sign of anomaly can be adjusted depending on how conditions in the furnace reflected in the evaluation value EV deteriorate.

[0044] Embodiments of the present invention are not limited to those described above and various modifications may be made thereto. For example, although the plurality of sensors S1 to Sn are shaft pressure sensors in the embodiments described above, temperature sensors or other types of sensors installed on the blast furnace may be used as long as they are capable of detecting anomalies.

[0045] Although the evaluation value calculating unit 11 calculates either the Q statistic index or the T^2 statistic index as the evaluation value EV in the embodiments, the evaluation value calculating unit 11 may calculate both of them as evaluation values EV to detect an anomaly. In this case, an alarm may be output when an anomaly or a premonitory sign of anomaly is detected with both the evaluation values EV, or may be output when an anomaly or a premonitory sign of anomaly is detected with one of the evaluation values EV. Although a statistic is calculated as the evaluation value EV in the embodiments described above, any technique that unifies a plurality of pieces of input data into an anomaly index may be used. For example, a known technique, such as independent component analysis or machine learning technique, may be used to unify the input data into a single index.

[0046] Although the evaluation value calculating unit 11 calculates one evaluation value EV in the embodiments described above, the evaluation value calculating unit 11 may calculate, for example, two evaluation values EV for upper and lower levels in accordance with the installation heights of the sensors S1 to Sn, so as to detect an anomaly for each of the evaluation values EV. In the embodiments described above, the anomaly detecting unit 12 determines whether, in a determination period, the cumulative period during which the evaluation value EV is greater than the anomaly premonitory sign threshold EVref2 is longer than or equal to the set period PT. However, the anomaly detecting unit 12 may determine that there is a premonitory sign of anomaly when simply a period during which the anomaly premonitory sign threshold EVref2 is continuously exceeded is longer than or equal to the set period PT.

Reference Signs List

[0047]

1:	blast furnace
10:	anomaly determining apparatus
11:	evaluation value calculating unit
12:	anomaly detecting unit
13:	information output unit
D1	to Dn: measurement data
DB:	database
EV:	evaluation value
EVref1:	anomaly threshold
EVref2:	anomaly premonitory sign threshold
I:	time integral
Iref:	integral threshold
PT:	set period
S1 to Sn:	sensor(s)

Claims

1. A blast furnace anomaly determining apparatus that detects an anomaly in a blast furnace using a plurality of sensors installed at different positions of the blast furnace, the anomaly determining apparatus comprising:

    an evaluation value calculating unit configured to calculate an evaluation value from a plurality of pieces of measurement data detected by the plurality of sensors; and
    an anomaly detecting unit configured to detect an anomaly in the blast furnace on the basis of the evaluation value calculated by the evaluation value calculating unit using an anomaly threshold and an anomaly premonitory sign threshold smaller than the anomaly threshold,
    wherein if the evaluation value is greater than the anomaly threshold, the anomaly detecting unit determines that there is an anomaly, and if a period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to a set period, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

2. The blast furnace anomaly determining apparatus according to Claim 1, wherein the anomaly detecting unit determines, every predetermined determination period, whether a cumulative period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to the set period, and if the cumulative period is longer than or equal to the set period, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

3. The blast furnace anomaly determining apparatus according to Claim 1 or Claim 2, wherein if a time integral of the evaluation value is greater than an integral threshold, the anomaly detecting unit determines that there is a premonitory sign of anomaly.

4. The blast furnace anomaly determining apparatus according to any one of Claim 1 to Claim 3, wherein the evaluation value calculating unit performs principal component analysis on the plurality of pieces of measurement data to calculate a Q statistic or a T^2 statistic, and calculates the evaluation value on the basis of the calculated Q statistic or T^2 statistic.

5. The blast furnace anomaly determining apparatus according to any one of Claim 1 to Claim 4, wherein the plurality of sensors are constituted by shaft pressure sensors installed at different positions in height direction and different positions in circumferential direction of the blast furnace.

6. A blast furnace anomaly determining method for detecting an anomaly in a blast furnace using a plurality of sensors installed at different positions of the blast furnace, the anomaly determining method comprising:

    an evaluation value calculating step of calculating an evaluation value from a plurality of pieces of measurement data detected by the plurality of sensors; and
    an anomaly detecting step of detecting an anomaly in the blast furnace on the basis of the calculated evaluation value using an anomaly threshold and an anomaly premonitory sign threshold smaller than the anomaly threshold,
    wherein if the evaluation value is greater than the anomaly threshold, the anomaly detecting step determines that there is an anomaly, and if a period during which the evaluation value is greater than the anomaly premonitory sign threshold is longer than or equal to a set period, the anomaly detecting step determines that there is a premonitory sign of anomaly.

7. The blast furnace anomaly determining method according to Claim 6, wherein the anomaly premonitory sign threshold is determined using an evaluation value of the plurality of pieces of measurement data calculated when variation of some pressure values of the plurality of pieces of measurement data during usual operation exceeds a predetermined range of variation in pressure values in a normal state.

8. A blast furnace operating method comprising operating a blast furnace while making a determination of an anomaly in the blast furnace using the blast furnace anomaly determining apparatus according

to any one of Claim 1 to Claim 5.

9. A hot metal producing method comprising producing hot metal with the blast furnace operating method according to Claim 8.

FIG. 1

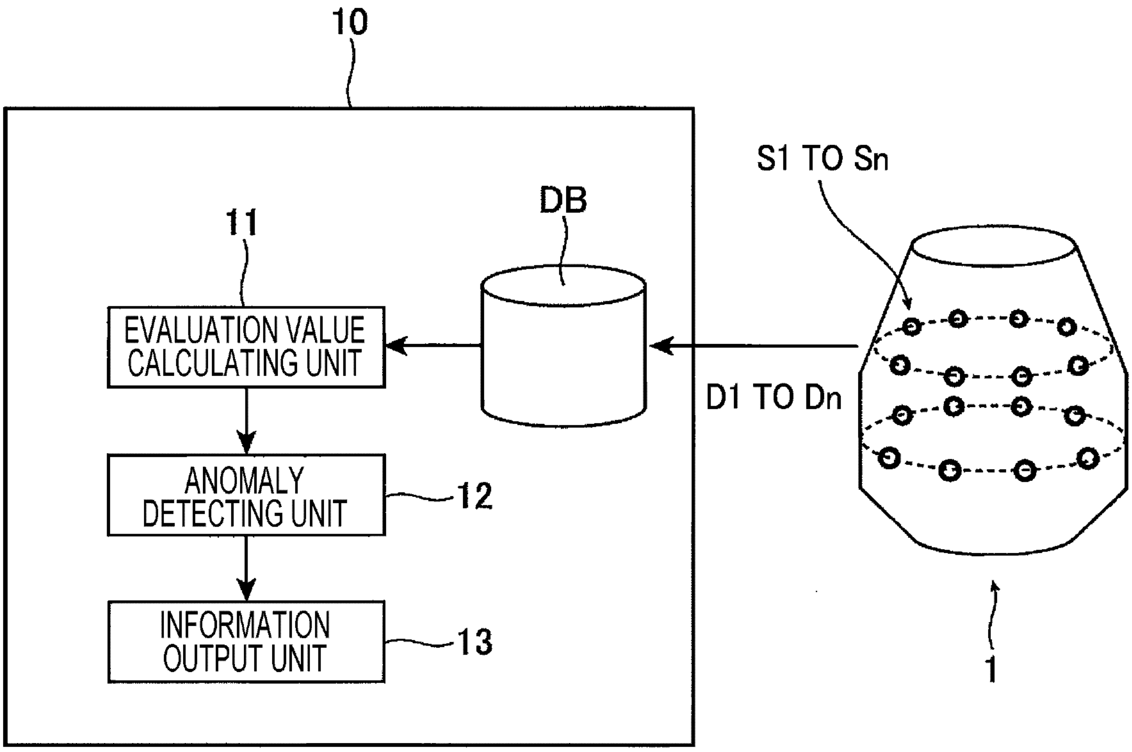

10
11
EVALUATION VALUE CALCULATING UNIT
DB
ANOMALY DETECTING UNIT
12
INFORMATION OUTPUT UNIT
13
S1 TO Sn
D1 TO Dn
1

FIG. 2

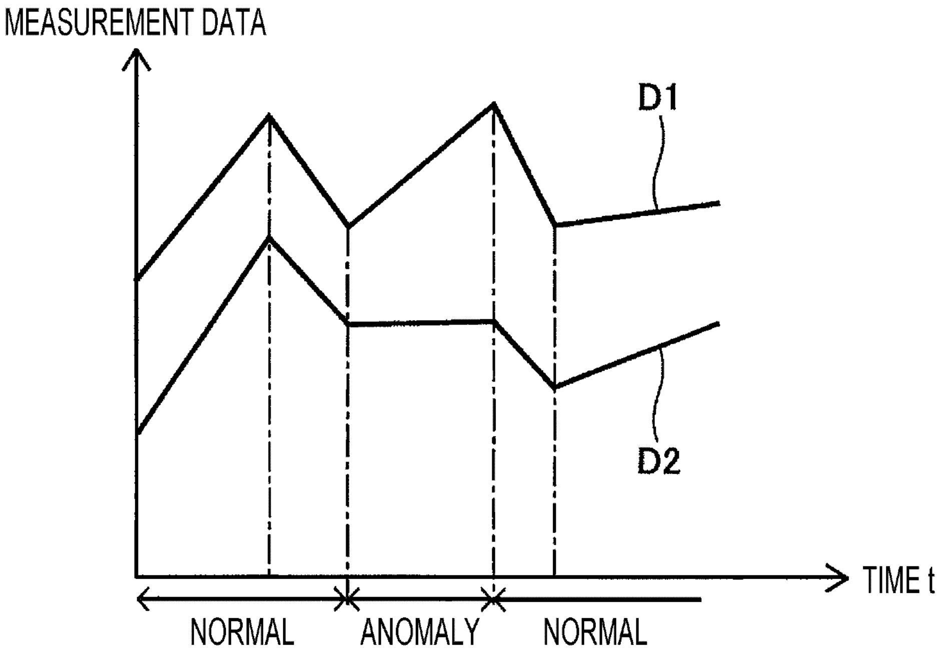

MEASUREMENT DATA
D1
D2
TIME t
NORMAL
ANOMALY
NORMAL

FIG. 3

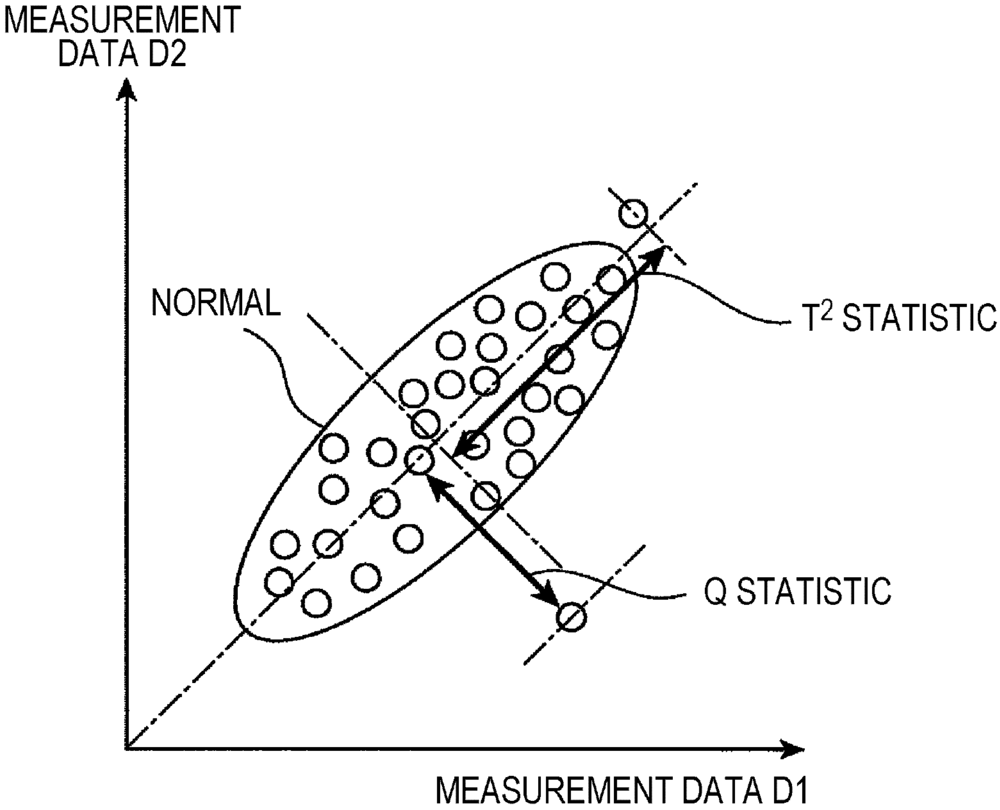

MEASUREMENT
DATA D2
NORMAL
T2 STATISTIC
Q STATISTIC
MEASUREMENT DATA D1

FIG. 4

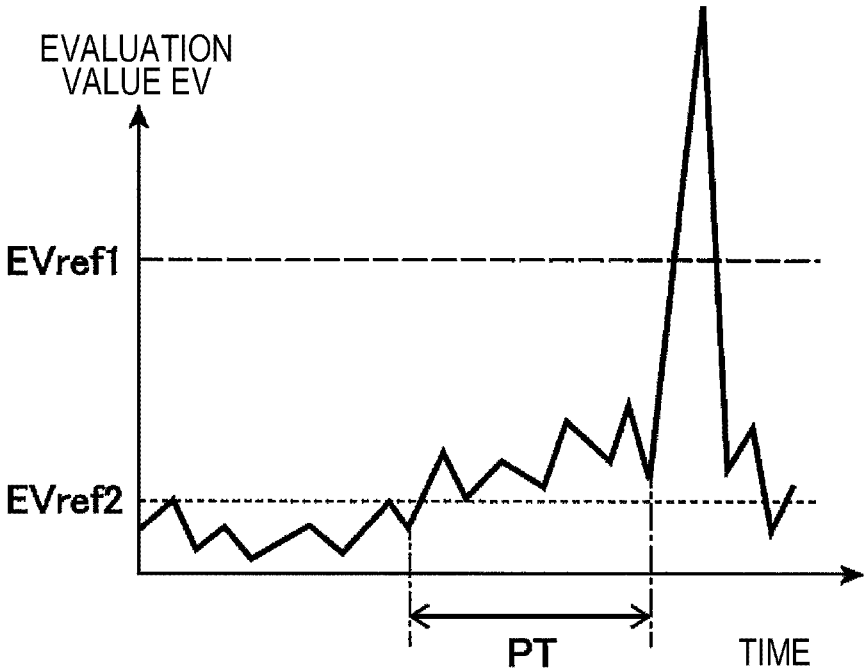

EVALUATION
VALUE EV
EVref1
EVref2
PT
TIME

FIG. 5

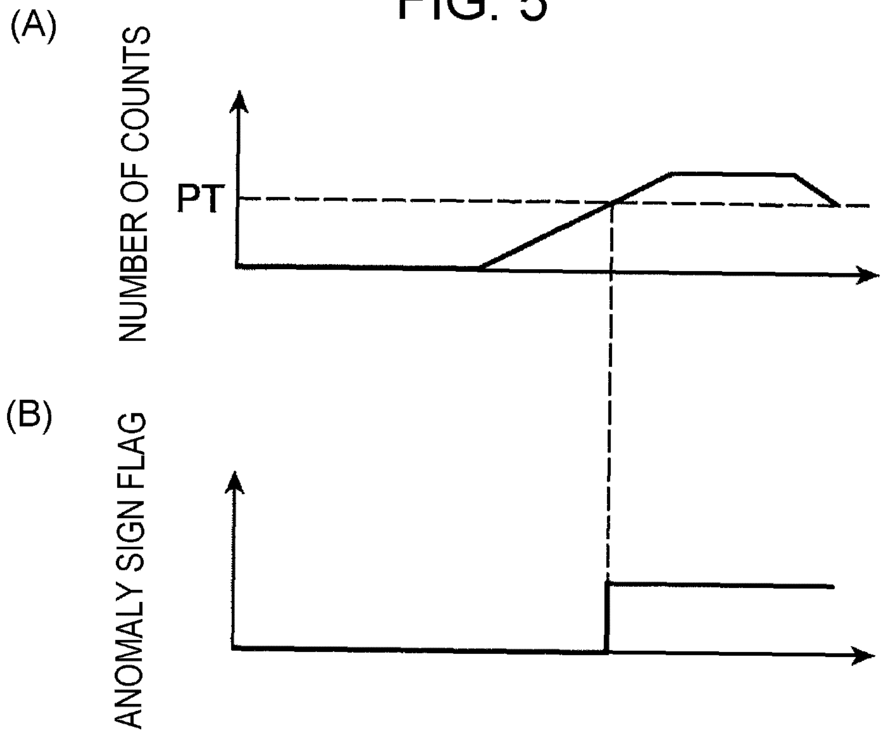

(A)
NUMBER OF COUNTS
PT
(B)
ANOMALY SIGN FLAG

FIG. 6

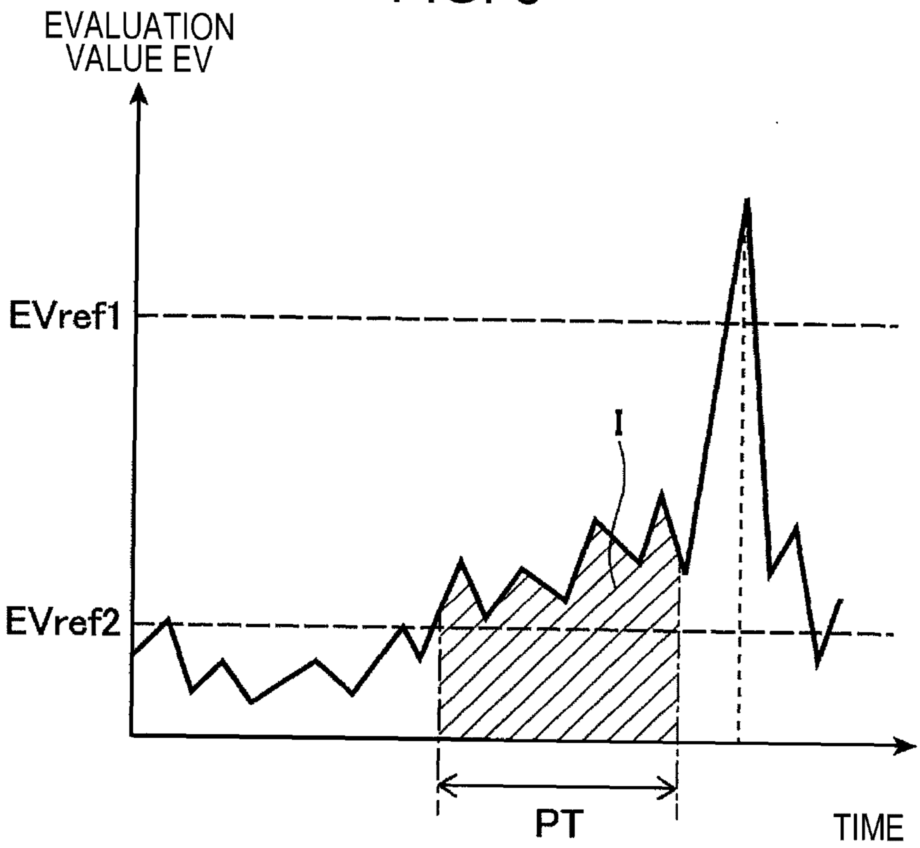
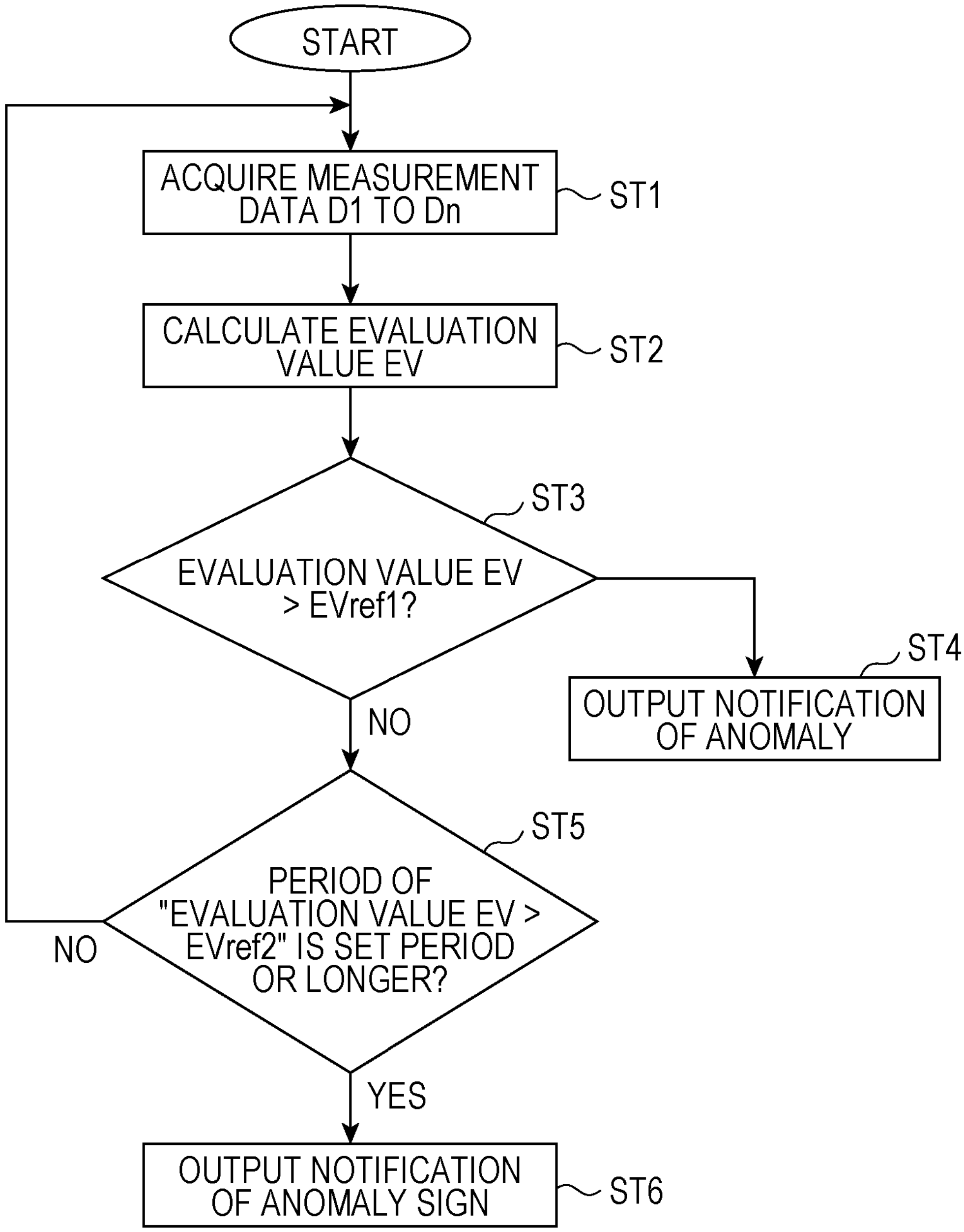

EVALUATION VALUE EV
EVref1
EVref2
I
PT
TIME

FIG. 7


START
ACQUIRE MEASUREMENT DATA D1 TO Dn
ST1
CALCULATE EVALUATION VALUE EV
ST2
EVALUATION VALUE EV > EVref1?
ST3
NO
OUTPUT NOTIFICATION OF ANOMALY
ST4
PERIOD OF "EVALUATION VALUE EV > EVref2" IS SET PERIOD OR LONGER?
ST5
NO
YES
OUTPUT NOTIFICATION OF ANOMALY SIGN
ST6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/031287

A. CLASSIFICATION OF SUBJECT MATTER
C21B 5/00(2006.01)i; C21B 7/24(2006.01)i
FI: C21B7/24 303; C21B5/00 323
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21B5/00; C21B7/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2017-128805 A (JFE STEEL CORPORATION) 27 July 2017 (2017-07-27)	1-9
A	WO 2014/203509 A1 (JFE STEEL CORPORATION) 24 December 2014 (2014-12-24)	1-9
A	JP 63-297513 A (KOBE STEEL, LTD.) 05 December 1988 (1988-12-05)	1-9
A	US 2009/0093973 A1 (SADRI, Afshin) 09 April 2009 (2009-04-09)	1-9
A	US 2012/0166107 A1 (GERRITSEN, Terry) 28 June 2012 (2012-06-28)	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 October 2020 (15.10.2020)	27 October 2020 (27.10.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application no.
PCT/JP2020/031287

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2017-128805 A	27 Jul. 2017	(Family: none)	
WO 2014/203509 A1	24 Dec. 2014	US 2016/0153062 A1	
JP 63-297518 A	05 Dec. 1988	(Family: none)	
US 2009/0093978 A1	09 Apr. 2009	WO 2009/039665 A1	
US 2012/0166107 A1	28 Jun. 2012	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2017128805 A **[0006]**