



(11)

EP 4 385 928 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.06.2024 Bulletin 2024/25

(51) International Patent Classification (IPC):
B65H 63/02 ^(2006.01) **B65H 63/04** ^(2006.01)
D01H 13/16 ^(2006.01) **D01H 13/20** ^(2006.01)

(21) Application number: **23209688.3**

(52) Cooperative Patent Classification (CPC):
B65H 63/02; B65H 63/04; D01H 13/16;
D01H 13/20; B65H 2701/31

(22) Date of filing: 14.11.2023

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
 GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
 NO PL PT RO RS SE SI SK SM TR**
 Designated Extension States:
BA
 Designated Validation States:
KH MA MD TN

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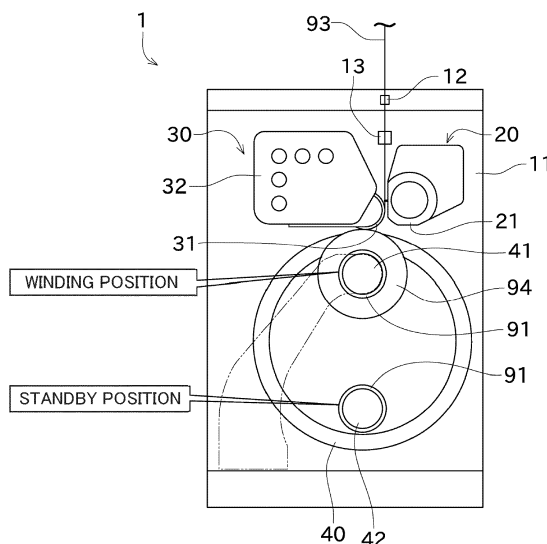
(30) Priority: 16.12.2022 JP 2022201332
27.06.2023 JP 2023104891

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(54) TENSION ABNORMALITY DETECTION DEVICE, TENSION ABNORMALITY DETECTION METHOD, AND TENSION ABNORMALITY DETECTION PROGRAM

(57) Provided is a tension abnormality detection device (10) capable of accurately detecting various abnormalities related to tension of a thread wound by a thread winding machine (1), with a simple method. The tension abnormality detection device (10) includes a control device (50) and a tension sensor (13) for detecting the tension of the thread wound by the thread winding machine (1). The control device (50) executes processing for acquiring an autoencoder (124) trained to compress a normal tension waveform and then restore the normal tension waveform, and processing for detecting abnormality in the tension of the thread wound by the thread winding machine (1), based on a degree of similarity between an input tension waveform obtained from the tension sensor (13) and an output tension waveform obtained by inputting the input tension waveform to the autoencoder (124).

FIG.1



Description

TECHNICAL FIELD

[0001] The present disclosure relates to a tension abnormality detection device, a tension abnormality detection method, and a tension abnormality detection program.

BACKGROUND ART

[0002] JP 2002-302824A (Patent Document 1) discloses a method for detecting an abnormality in a step of using a winding device to wind a thread spun from a spinning device. The thread path is provided with a tension measurement means. The tension measurement means measures the tension of the thread and obtains the average value of the tension and the standard deviation of the tension during a predetermined sampling period. In the method of Patent Document 1, the obtained average value of the tension is compared with the upper and lower thresholds therefor, and it is detected whether or not there is an abnormality by comparing the obtained standard deviation of the tension and the upper threshold.

[0003] JP 2002-302824A is an example of related art.

[0004] In the method of Patent Document 1, abnormalities are uniformly detected based on the average value of the tension and the standard deviation of the tension. However, since there are various patterns of abnormalities in tension, it is not easy to accurately detect various abnormalities in tension based on only the average value of the tension and the standard deviation of the tension.

[0005] The present disclosure has been made in view of the above circumstances, and a main purpose thereof is to provide a tension abnormality detection device, a tension abnormality detection method, and a tension abnormality detection program, according to which it is possible to accurately detect various abnormalities related to tension of a thread wound by a thread winding machine.

SUMMARY OF THE INVENTION

[0006] In one example of the present disclosure, a tension abnormality detection device is provided. The tension abnormality detection device includes a control device and a tension sensor for detecting tension of a thread wound by a thread winding machine. The control device executes processing for acquiring an autoencoder trained to compress a normal tension waveform and then restore the normal tension waveform, and processing for detecting an abnormality in the tension of the thread wound by the thread winding machine, based on a degree of similarity between an input tension waveform obtained from the tension sensor and an output tension waveform obtained by inputting the input tension waveform to the autoencoder.

[0007] In this tension abnormality detection device, an autoencoder trained based on a tension waveform with normal tension is used to detect an abnormality in the tension of a thread. For this reason, various abnormalities that deviate from normal tension can be detected. For example, abnormalities that cannot be detected with only the magnitude of the tension or the degree of change in the tension are detected.

[0008] In one example of the present disclosure, the control device further executes training processing for generating the autoencoder using a normal tension waveform.

[0009] As a result, the training processing is executed by the tension abnormality detection device. Due to the tension abnormality detection device having a learning function, the tension abnormality detection device can generate the autoencoder by itself.

[0010] In one example of the present disclosure, the thread winding machine winds thread on a bobbin while causing the thread to perform a traversing motion, and the tension sensor is configured to detect tension by intermittently coming into contact with the thread according to the traversing motion of the thread.

[0011] As a result, the data detected by the tension sensor that intermittently comes into contact with the thread includes not only the maximum value of the tension but also a change trend indicating how the tension changes over time. As a result, the tension waveform includes a large number of features, and therefore an autoencoder for accurately detecting the degree of abnormality in the tension of the thread is generated.

[0012] In one example of the present disclosure, in the detecting processing, abnormality of tension is detected if the degree of similarity is greater than or equal to a predetermined threshold. Normality of tension is detected if the degree of similarity is less than the predetermined threshold.

[0013] As a result, the tension abnormality detection device can detect a tension abnormality according to the threshold.

[0014] In one example of the present disclosure, the tension abnormality detection device further includes a display unit. The control device further executes processing for creating a graph showing change over time in the degree of similarity and displaying the graph on the display unit.

[0015] As a result, for example, an administrator or an operator can intuitively grasp the degree of abnormality in the tension.

[0016] In one example of the present disclosure, the control device executes the detecting processing while the thread winding machine winds the thread.

[0017] As a result, the tension abnormality detection device can detect the degree of abnormality in the tension in real time or at a timing close to real time. For this reason, if the tension is abnormal, the administrator or operator can also perform processing such as interrupting the winding.

[0018] In one example of the present disclosure, the control device further executes processing for acquiring an estimation model trained to receive input of a tension waveform and output a type of the abnormality, and processing for, if abnormality of tension is detected in the detecting processing, identifying the type of the abnormality based on the input tension waveform and the estimation model.

[0019] As a result, the tension abnormality detection device can not only detect the occurrence of a tension abnormality, but also identify the type of the tension abnormality that has occurred.

[0020] In another example of the present disclosure, a tension abnormality detection method to be performed by a tension abnormality detection device is provided. The tension abnormality detection device includes a tension sensor for detecting tension of a thread wound by the thread winding machine. The tension abnormality detection method includes a step of acquiring an autoencoder trained to compress a normal tension waveform and then restore the normal tension waveform; and a step of detecting abnormality in the tension of the thread wound by the thread winding machine, based on a degree of similarity between an input tension waveform obtained from the tension sensor and an output tension waveform obtained by inputting the input tension waveform to the autoencoder.

[0021] In this tension abnormality detection method, an autoencoder trained based on a tension waveform with normal tension is used to detect abnormality in the tension of a thread. For this reason, various abnormalities that deviate from normal tension can be detected. For example, abnormalities that cannot be detected with only the magnitude of the tension or degree of change in the tension are detected.

[0022] Another example of the present disclosure provides a tension abnormality detection program to be executed by a tension abnormality detection device. The tension abnormality detection device includes a tension sensor for detecting tension of a thread wound by a thread winding machine. The tension abnormality detection program causes the tension abnormality detection device to execute: a step of acquiring an autoencoder trained to compress a normal tension waveform and then restore the normal tension waveform; and a step of detecting abnormality in the tension of the thread wound by the thread winding machine based on a degree of similarity between an input tension waveform obtained from the tension sensor and an output tension waveform obtained by inputting the input tension waveform to the autoencoder.

[0023] In this tension abnormality detection program, an autoencoder trained based on a tension waveform with normal tension is used to detect abnormality in the tension of a thread. For this reason, various abnormalities that deviate from normal tension can be detected. For example, abnormalities that cannot be detected with only the magnitude of the tension or the degree of change in

the tension are detected.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0024]**

FIG. 1 is a front view of a thread winding machine according to one embodiment.

FIG. 2 is a diagram showing a side view of the thread winding machine.

FIG. 3 is a diagram showing a block diagram of the thread winding machine.

FIG. 4 is a diagram showing a method for obtaining an output tension waveform from an input tension waveform using a conversion model.

FIG. 5 is a graph showing an input tension waveform, an output tension waveform, and a score when there is no tension abnormality.

FIG. 6 is a graph showing an input tension waveform, an output tension waveform, and a score when there is a tension abnormality.

FIG. 7 is a diagram showing a flowchart for determining whether or not there is a tension abnormality.

FIG. 8 is a diagram showing a flowchart showing processing for causing an operator to determine whether or not there is a tension abnormality.

FIG. 9 is a diagram showing an example of a hardware configuration of a control device.

FIG. 10 is a diagram showing an example of a training data set.

FIG. 11 is a diagram showing an example of a functional configuration of a control device.

FIG. 12 is a diagram conceptually showing training processing performed by a training unit.

FIG. 13 is a diagram conceptually showing abnormality detection processing performed by a detection unit.

FIG. 14 is a diagram showing an example of a device configuration of an abnormality detection system.

FIG. 15 is a diagram showing an example of a training data set.

FIG. 16 is a diagram showing an example of a functional configuration of a control device.

FIG. 17 is a diagram conceptually showing training processing performed by a training unit.

FIG. 18 is a diagram conceptually showing processing for identifying an abnormality type, performed by an identification unit.

EMBODIMENTS OF THE INVENTION

[0025] Hereinafter, each embodiment according to the present invention will be described with reference to the drawings. In the following description, identical parts and constituent elements are denoted by identical reference numerals. Their names and functions are also the same. Accordingly, detailed description thereof will not be repeated. Note that each embodiment and modified exam-

ple described below may also be selectively combined with each other as appropriate.

A. Thread Winding Machine 1

[0026] Next, an embodiment of the present disclosure will be described with reference to the drawings. FIG. 1 is a front view of a thread winding machine 1 according to an embodiment of the present disclosure. FIG. 2 is a side view of the thread winding machine 1. FIG. 3 is a block diagram of the thread winding machine 1. In the following description, upstream or downstream in the travel direction of the thread is simply referred to as upstream or downstream in some cases.

[0027] A spinning machine (not shown) is arranged upstream of the thread winding machine 1 shown in FIG. 1. The spinning machine produces a thread 93 and supplies the thread 93 to the thread winding machine 1. The thread winding machine 1 winds the thread 93 around a bobbin 91 to manufacture a package 94. As shown in FIG. 1, the package 94 is formed by winding the thread 93 on the bobbin 91 at an upper winding position to form a thread layer. On the other hand, the thread 93 is not wound on the bobbin 91 at the lower standby position.

[0028] The thread 93 is a highly stretchable synthetic thread such as nylon or polyester. More specifically, the thread 93 is, for example, FDY (Fully Draw Yarn) or POY (Partially Oriented Yarn). However, the types of the thread 93 are not limited to these, and a tension abnormality detection device 10, which will be described later, can be applied also to threads other than those described above.

[0029] Also, as shown in FIG. 2, in the present embodiment, a plurality of threads 93 arranged side by side in the axial direction of the first bobbin holder 41 (second bobbin holder 42) are supplied from a thread feed roller 100 to the thread winding machine 1 from the spinning machine. Also, a plurality of bobbins 91 are arranged side by side in the axial direction of the first bobbin holder 41 (second bobbin holder 42). The thread winding machine 1 winds a plurality of threads 93 onto the bobbins 91 to manufacture a plurality of packages 94.

[0030] Details of the thread winding machine 1 will be described below. As shown in FIG. 1, the thread winding machine 1 includes a frame 11, a support point guide 12, a first housing 20, a second housing 30, and a turret plate (bobbin holder moving mechanism) 40.

[0031] The frame 11 is a member that holds each part of the thread winding machine 1. The first housing 20 and the second housing 30 are mounted on the frame 11. The first housing 20 and the second housing 30 can move up and down with respect to the frame 11.

[0032] The support point guide 12 is arranged on the frame 11. The support point guide 12 guides the thread 93 supplied to the thread winding machine 1 from the spinning machine. Specifically, the support point guide 12 has a wall portion that comes into contact with the thread 93, and restricts the position of the thread 93 such

that the thread 93 does not deviate from the thread path.

[0033] A traverse device 21 is attached to the first housing 20. The traverse device 21 causes the thread 93 fed downstream to perform a traversing motion by moving back and forth on the winding width of the package 94 along the axial direction of a later-described first bobbin holder 41 while a later-described traverse guide 23 engages with the thread 93. A thread layer is formed on the bobbin 91 or the package 94 by this traversing motion of the thread 93. As shown in FIG. 3, the traverse device 21 includes a traverse cam 22 and a traverse guide 23.

[0034] The traverse cam 22 is a roller-shaped member arranged parallel to the bobbin 91 or the package 94. A spiral cam groove is formed on the outer peripheral surface of the traverse cam 22. The traverse cam 22 is rotationally driven by a traverse motor 51.

[0035] The traverse motor 51 is controlled by a later-described control device 50. The traverse guide 23 is a part that engages with the thread 93. The leading end of the traverse guide 23 has, for example, a substantially U-shaped guide portion, which engages with the thread 93 so as to sandwich the thread 93 in the winding width direction. The base end of the traverse guide 23 is located in the cam groove of the traverse cam 22. With this configuration, by rotationally driving the traverse cam 22, the traverse guide 23 can be moved back and forth in the winding width direction with the support point guide 12 serving as a support point.

[0036] A contact roller 31 is rotatably mounted on the second housing 30. When the thread 93 is wound, the contact roller 31 is driven to rotate while in contact with the thread layer of the package 94 with a predetermined pressure, whereby the thread 93 from the traverse guide 23 is fed to the thread layer of the package 94 and the thread layer shape of the package 94 is adjusted. Note that the contact roller 31 may be rotationally driven using a drive unit such as a motor.

[0037] An operation panel 32 is provided on the second housing 30. The operation panel 32 is a device operated by an operator. The operator gives instructions to the thread winding machine 1 by operating the operation panel 32. Instructions given by the operator include, for example, starting winding, stopping winding, and changing winding conditions.

[0038] A tension sensor 13 is provided on the thread path from the spinning machine to the traverse device 21. Specifically, the tension sensor 13 is provided downstream of the support point guide 12 and upstream of the traverse device 21 in the travel direction of the thread 93. Accordingly, the tension sensor 13 detects the tension of the thread 93 that is moved back and forth by the traverse device 21. The tension sensor 13 has a pair of arm portions (not shown). One arm portion comes into contact with the thread 93 at one end of the traversing motion. The other arm portion comes into contact with the thread 93 at the other end of the traversing motion. That is, the tension sensor 13 intermittently comes into contact with the thread 93 performing a traversing mo-

tion. Also, a strain gauge is provided on the arm portion, and the strain of the arm portion detected by the strain gauge correlates with the tension of the thread 93. Accordingly, the tension of the thread 93 can be obtained based on the signal output by the strain gauge. A signal indicating the value of the tension detected by the tension sensor 13 is output to the control device 50, which will be described later. Also, the signal output by the tension sensor 13 includes a tension waveform that indicates change in the tension over time.

[0039] Note that the tension sensor 13 described above is merely an example, and a tension sensor 13 having a configuration different from that of the present embodiment may also be used. For example, the tension sensor 13 is not limited to intermittently coming into contact with the thread 93, and may be configured to continuously be in contact with the thread 93. Also, the tension sensor 13 may detect tension using a spring or a piezo-electric element instead of the strain gauge.

[0040] As shown in FIG. 3, the thread winding machine 1 has a display unit 14. The display unit 14 is a display capable of displaying information. The display unit 14 is, for example, a liquid crystal display or an organic EL display. The display unit 14 displays an image output by the control device 50, which will be described later, on a screen.

[0041] The turret plate 40 is a disk-shaped member. The turret plate 40 is rotatably mounted on the frame 11. The turret plate 40 can rotate using a normal line passing through the center of the disk as a rotation axis. The turret plate 40 is rotationally driven by a turret motor 53 shown in FIG. 3. The turret motor 53 is controlled by the control device 50, which will be described later.

[0042] A first bobbin holder 41 and a second bobbin holder 42 are respectively provided at two locations on the turret plate 40 that oppose each other across the center of the disk. A plurality of bobbins 91 can be mounted side by side in the axial direction of the first bobbin holder 41 on the first bobbin holder 41. The plurality of bobbins 91 can be mounted side by side in the axial direction of the second bobbin holder 42 on the second bobbin holder 42. The positions of the first bobbin holder 41 and the second bobbin holder 42 can be changed by rotating the turret plate 40. Note that another device may be used instead of the turret plate 40, as long as the positions of the first bobbin holder 41 and the second bobbin holder 42 can be changed.

[0043] The first bobbin holder 41 is rotatable with respect to the turret plate 40 using the axis position of the first bobbin holder 41 as the center of rotation. The first bobbin holder 41 is rotationally driven by a first bobbin holder motor 54 shown in FIG. 3. Similarly, the second bobbin holder 42 is rotatable with respect to the turret plate 40 using the axis position of the second bobbin holder 42 as the center of rotation. The second bobbin holder 42 is rotationally driven by a second bobbin holder motor 55 shown in FIG. 3. The first bobbin holder motor 54 and the second bobbin holder motor 55 are controlled

by the control device 50, which will be described later.

[0044] Hereinafter, the first bobbin holder 41 and the second bobbin holder 42 are collectively referred to as bobbin holders 41 and 42. FIG. 1 shows a state in which the bobbin holders 41 and 42 are arranged side by side in the up-down direction. At this time, the position of the bobbin holders 41 and 42 on the higher side is the winding position, and the position of the bobbin holders 41 and 42 on the lower side is the standby position. The thread winding machine 1 produces the package 94 by winding the thread 93 around the bobbins 91 of the bobbin holders 41 and 42 at the winding position.

[0045] Also, if the packages 94 of the first bobbin holder 41 are fully wound by winding a predetermined amount of the thread 93, the positions of the first bobbin holder 41 and the second bobbin holder 42 are switched by rotating the turret plate 40. Thereafter, the packages 94 of the first bobbin holder 41 that are fully wound and are at the standby position are collected, and the thread 93 is wound onto the bobbins 91 of the second bobbin holder 42 that are at the winding position. New bobbins 91 are mounted on the first bobbin holder 41 from which the packages 94 have been collected.

[0046] The control device 50 includes a control unit 50a, a training unit 50b, a detection unit 50c, and a storage unit 50d. Specifically, the control device 50 is configured as a known computer, and includes a CPU (Central Processing Unit), RAM (Random Access Memory), SSD (Solid State Drive), and the like. A CPU is a type of processor. Programs and data for controlling the thread winding machine 1 are stored in advance in the SSD. Also, the SSD stores tension input from the tension sensor 13 in chronological order. Due to the CPU reading out the program to the RAM and executing the program, the control device 50 can operate as the control unit 50a, the training unit 50b, and the detection unit 50c. Also, the SSD corresponds to the storage unit 50d. Note that an HDD (Hard Disk Drive) or flash memory may be used instead of the SSD. Alternatively, a storage that is provided outside of the control device 50 and can communicate with the control device 50 may also be used as the storage unit.

[0047] The control unit 50a performs overall control of the control device 50. The control unit 50a processes the data input to the control device 50 from the outside or data stored in the storage unit 50d. The control unit 50a stores the data obtained through this processing in the storage unit 50d or outputs the data to the outside of the control device 50. The training unit 50b performs processing for constructing a conversion model using machine learning. Details of the conversion model constructed by the training unit 50b will be described later. The detection unit 50c performs detection processing for detecting an abnormality based on data externally input to the control device 50 and the conversion model constructed by the training unit 50b and stored in the storage unit 50d. The storage unit 50d stores data according to the processing of the control unit 50a.

[0048] FIG. 3 shows the tension abnormality detection device 10. The tension abnormality detection device 10 detects the degree of abnormality in the tension of the thread 93 wound by the thread winding machine 1. The tension abnormality detection device 10 includes a control device 50, a tension sensor 13, and a display unit 14. The control device 50 performs the following processing as a component of the tension abnormality detection device 10.

[0049] That is, the control unit 50a outputs data to the training unit 50b and the detection unit 50c for processing. The control unit 50a causes the storage unit 50d to store data obtained by the training unit 50b and the detection unit 50c performing processing. Also, the control unit 50a stores the tension waveform detected by the tension sensor 13 in the storage unit 50d. Note that a traverse motor 51, a turret motor 53, a first bobbin holder motor 54, and a second bobbin holder motor 55 are further included as objects to be controlled by the control unit 50a. The training unit 50b constructs a conversion model by performing machine learning based on a tension waveform stored in the storage unit 50d or a tension waveform based on the detection value of the tension input from the tension sensor 13. The detection unit 50c detects a degree of abnormality in the tension of the thread 93 wound by the thread winding machine 1 and determines whether or not there is an abnormality based on data input to the control device 50 from the outside (specifically, tension detected by the tension sensor 13) and a conversion model constructed by the training unit 50b and stored in the storage unit 50d. The determination result obtained through the processing of the detection unit 50c is output to the outside or stored in the storage unit 50d by the control unit 50a. The storage unit 50d stores data obtained through the processing of the control unit 50a, the training unit 50b, and the detection unit 50c, as described above.

[0050] The conversion model is an autoencoder, and is constructed by the training unit 50b performing the following machine learning. First, the operator or administrator instructs the training unit 50b to start machine learning. Upon receiving this instruction, the training unit 50b requests the tension sensor 13 to transmit the detection value of the tension. The tension sensor 13 outputs the detection value of the tension to the training unit 50b. The training unit 50b buffers the detection value of the tension input from the tension sensor 13. The processing for acquiring and buffering the detection value of the tension by the training unit 50b is performed repeatedly. Thereafter, the training unit 50b performs machine learning on the buffered detection value of the tension to construct a conversion model. Note that the detection value of the tension output by the tension sensor 13 may be stored in the storage unit 50d based on a request from the training unit 50b, and the training unit 50b may construct the conversion model by performing machine learning based on the content stored in the storage unit 50d. The conversion model constructed by the training unit 50b is stored in the storage unit 50d and set in the

detection unit 50c. This completes the machine learning.

[0051] Since the tension sensor 13 of this embodiment is configured to intermittently come into contact with the thread 93, the tension waveform is triangular. Also, training data for creating a conversion model is a tension waveform with normal tension. Only tension waveforms with normal tension are used to create the conversion model, and tension waveforms with abnormal tension are not used. Since the frequency of occurrence of an abnormality in tension is generally low, it is easy to prepare a tension waveform with normal tension.

[0052] A conversion model is constructed by performing unsupervised learning using the above training data for an input layer, an intermediate layer, and an output layer in a multi-layer neural network. The learning performed here is deep learning, and since feature amounts are specified through learning, input of feature amounts is unnecessary. By setting a tension waveform with normal tension for the conversion model constructed by performing this learning, important feature amounts included in the tension waveform are extracted and compressed into an intermediate layer (hidden layer), and thereafter a restored tension waveform is generated based on the feature amounts. That is, the conversion model is used such that if the input tension waveform is a tension waveform with normal tension, the output tension waveform will generate a tension waveform similar to the input tension waveform. Note that the method for constructing a conversion model of the present embodiment is an example, and another method can also be used.

[0053] As shown in FIG. 4, the conversion model is used by the detection unit 50c. Specifically, the detection unit 50c generates the output tension waveform based on the input tension waveform and the conversion model. Here, if the input tension waveform is a tension waveform with normal tension, the detection unit 50c generates a tension waveform similar to the input tension waveform as the output tension waveform. Then, if the input tension waveform is an abnormal tension waveform, the detection unit 50c generates a tension waveform different from the input tension waveform as the output tension waveform.

[0054] FIG. 5 shows a tension waveform (input tension waveform) in which no tension abnormality occurs, and an output tension waveform generated by the detection unit 50c based on the input tension waveform and the conversion model. Since the input tension waveform does not include a tension abnormality, the input tension waveform and the output tension waveform are substantially the same and have a high degree of similarity.

[0055] FIG. 6 shows a tension waveform (input tension waveform) in which a tension abnormality occurs, and an output tension waveform generated by the detection unit 50c based on the input tension waveform and the conversion model. Since the input tension waveform includes a tension abnormality, the degree of similarity between the input tension waveform and the output tension waveform is low in the time span when the tension ab-

normality occurs (the time span indicated by the dashed-line ellipse).

[0056] The detection unit 50c compares the input tension waveform and the output tension waveform, and detects the degree of abnormality in the tension of the thread 93 based on the degree of similarity between the input tension waveform and the output tension waveform. Various methods for obtaining a degree of correlation between two pieces of data can be used to compare the input tension waveform and the output tension waveform. In this embodiment, the Mahalanobis distance is used. The Mahalanobis distance is a virtual distance calculated with consideration given to the correlative relationship, and the distance decreases when the correlation is high. Note that since the Mahalanobis distance is publicly known, detailed description thereof is omitted. The detection unit 50c calculates the Mahalanobis distance for each time span based on the input tension waveform and the output tension waveform. Here, the correlation between the input tension waveform and the output tension waveform indicates the degree of similarity of the waveforms. That is, if the tension is normal, the degree of similarity between the input tension waveform and the output tension waveform is high, and the Mahalanobis distance is small. If the tension is abnormal, the degree of similarity between the input tension waveform and the output tension waveform decreases, and the Mahalanobis distance increases. Therefore, an increase in the Mahalanobis distance indicates a degree of abnormality in the tension. The Mahalanobis distance is hereinafter referred to as a score. As mentioned above, values other than the Mahalanobis distance can also be used as scores.

[0057] The score is low because the input tension waveform in FIG. 5 includes no tension abnormality. On the other hand, since the input tension waveform in FIG. 6 includes a tension abnormality, the score becomes high in the time span when the tension abnormality is included. By using the score, the degree of similarity between the input tension waveform and the output tension waveform, or in other words, the degree of abnormality in the tension, can be indicated by a specific numerical value.

[0058] Also, as shown in FIGS. 5 and 6, a threshold may be set for the score. In this case, the threshold is set in the detection unit 50c in advance. The threshold can be determined experimentally or empirically. The detection unit 50c may determine whether or not the tension is abnormal based on whether the score is greater than or equal to the threshold or less than the threshold.

[0059] In the example shown in FIG. 6, the tension is very large during the time span when the tension abnormality occurs, compared to other time spans. This is an example of a tension abnormality, and there are various types of tension abnormalities. Depending on the type of tension abnormality, the mode in which the tension changes may differ from those of other time spans. With this type of tension abnormality, the tension abnormality cannot be determined using only the magnitude of the

tension. However, by using the method of the present embodiment, even with this type of tension abnormality, the score is high, and therefore this type of tension abnormality can be detected.

[0060] Next, a flow of processing performed by the tension abnormality detection device 10 will be described mainly with reference to FIG. 7.

[0061] The operator or administrator sets the above-described threshold in the detection unit 50c in advance. Thereafter, the operator or administrator instructs the detection unit 50c to detect abnormality in the tension. Also, the detection unit 50c determines whether or not the tension abnormality detection timing has been reached (S101), and if there is an instruction from an operator or administrator, the detection unit 50c determines that the detection timing has been reached.

[0062] Next, the detection unit 50c generates an output tension waveform (S 102). Specifically, the detection unit 50c requests the tension sensor 13 to transmit the detection value of the tension if it is determined that the detection timing has been reached. The tension sensor 13 outputs the detection value of the tension to the detection unit 50c. The detection unit 50c buffers the detection value of the tension input from the tension sensor 13. Thereafter, the detection unit 50c generates an output tension waveform based on the input tension waveform based on the buffered detection value of the tension and the conversion model stored in the storage unit 50d. Next, the detection unit 50c compares the input tension waveform and the output tension waveform, and calculates the score as described above (S103).

[0063] Next, the detection unit 50c determines whether or not the score is greater than or equal to the threshold (S104). If the detection unit 50c determines that the score is greater than or equal to the threshold, the detection unit 50c determines that the tension is abnormal (S105). In this case, the control unit 50a or the detection unit 50c may also store the time when the tension was abnormal, or the like. Also, the control unit 50a or the detection unit 50c may notify the operator by displaying that the tension is abnormal on the display unit 14. Alternatively, the control unit 50a may instruct interruption of the winding of the thread 93. On the other hand, if it is determined that the score is less than the threshold, the detection unit 50c determines that the tension is normal (S106).

[0064] In the example shown in FIG. 7, the detection unit 50c determines whether or not the tension is abnormal. Alternatively, as shown in FIG. 8, the detection unit 50c may simply present the score. In this case, the operator or administrator looks at the score presented by the detection unit 50c and determines whether or not the tension is abnormal.

[0065] In the flowchart of FIG. 8, steps S201 to S203 are the same processing as steps S101 to S103 described above, and therefore description thereof will be omitted. After calculating the score, the detection unit 50c displays the score as a numerical value and a graph on the display unit 14 (S204).

[0066] In the processing shown in FIGS. 7 and 8, the degree of abnormality in the tension of the thread 93 being wound is detected while the thread winding machine 1 winds the thread 93. In other words, the degree of abnormality in the tension is detected in real time. Alternatively, data relating to the tension may also be stored while the thread 93 is being wound, and after the thread 93 is wound, the degree of abnormality in the tension may also be detected based on the stored data.

[0067] As described above, the tension abnormality detection device 10 of the present embodiment detects the degree of abnormality in the tension of the thread 93 wound by the thread winding machine 1. The tension abnormality detection device 10 includes the tension sensor 13, the training unit 50b, the storage unit 50d, and the detection unit 50c. The tension sensor 13 detects the tension of the thread 93 wound by the thread winding machine 1. The training unit 50b constructs a conversion model that generates the same waveform based on a tension waveform with normal tension, by performing machine learning of the tension waveform with normal tension using an autoencoder. The storage unit 50d stores the conversion model constructed by the training unit 50b. The detection unit 50c generates an output tension waveform based on the input tension waveform obtained based on the tension detected by the tension sensor 13 and the conversion model that has learned the tension waveform, and detects the degree of abnormality in the tension of the thread 93 wound by the thread winding machine 1 based on the degree of similarity between the input tension waveform and the output tension waveform.

[0068] Since the tension waveform with normal tension is learned to create a conversion model, various abnormalities that deviate from normal tension can be detected. In particular, by constructing a conversion model through machine learning of a tension waveform using an autoencoder, it is possible to detect abnormalities that cannot be detected with only the magnitude of the tension or the degree of change in the tension.

[0069] In the tension abnormality detection device 10 of the present embodiment, the thread winding machine 1 winds the thread 93 onto the package 94 while causing the thread 93 to perform a traversing motion. The tension sensor 13 detects the tension by intermittently coming into contact with the thread 93 according to the traversing motion of the thread 93.

[0070] The data detected by the tension sensor 13 intermittently coming into contact with the thread 93 includes not only the maximum value of the tension but also the change trend showing how the tension changes with time. For this reason, since the tension waveform includes many features, a model for accurately detecting the degree of abnormality in the tension of the thread 93 can be created.

[0071] In the tension abnormality detection device 10 of the present embodiment, the detection unit 50c compares the input tension waveform and the output tension waveform to calculate a score that quantifies the degree

of abnormality.

[0072] This makes it possible to specifically obtain the degree of abnormality in the tension.

[0073] In the tension abnormality detection device 10 of the present embodiment, a threshold is set in advance in the detection unit 50c, and the detection unit 50c determines that the tension is abnormal if the score is greater than or equal to the threshold, and determines that the tension is normal if the score is less than the threshold.

[0074] This makes it possible to determine whether or not the tension is abnormal.

[0075] The tension abnormality detection device 10 of the present embodiment includes the display unit 14, and the detection unit 50c performs control for creating a graph showing the change in the score over time and displaying the graph on the display unit 14.

[0076] As a result, for example, an administrator or an operator can intuitively grasp the degree of abnormality in the tension.

[0077] In the tension abnormality detection device 10 of the present embodiment, the detection unit 50c detects the degree of abnormality in the tension of the thread 93 being wound while the thread winding machine 1 winds the thread 93.

[0078] As a result, the degree of abnormality in the tension can be detected in real time or at a timing close to real time. For this reason, for example, if the tension is abnormal, it is possible to perform processing such as interrupting the winding.

[0079] Although the preferred embodiment of the present disclosure has been described above, the above configuration can be modified as follows, for example.

[0080] The flowcharts shown in the above embodiments are examples, and some of the processing may be omitted, the content of some of the processing may be changed, or new processing may be added.

[0081] Although the traverse device 21 of the above embodiment is of a cam drum type, it may have a different configuration as long as the traverse guide 23 can be moved back and forth in the winding width direction. For example, instead of the traverse device 21, a rotary traverse device using rotating blades or a belt-type traverse device in which a traverse guide is reciprocally driven by a belt can also be used.

[0082] In the above embodiment, an example in which the present invention is applied to a thread winding machine that winds thread produced by a spinning machine has been described, but instead of the thread winding machine, the present invention can also be applied to a false twisting machine or a rewinding machine.

B. Hardware Configuration of Control Device 50

[0083] Next, the hardware configuration of the control device 50 shown in FIG. 3 will be described with reference to FIG. 9. FIG. 9 is a diagram showing an example of the hardware configuration of the control device 50.

[0084] The control device 50 includes the above-de-

scribed storage unit 50d (see FIG. 3), a processor 101, a communication interface 104, a display interface 105, and an input interface 107. These components are connected to a bus 115. Examples of the storage unit 50d include a ROM (Read Only Memory) 102, a RAM 103, an auxiliary storage device 120, and the like.

[0085] The processor 101 is constituted by, for example, at least one integrated circuit. An integrated circuit can be constituted by, for example, at least one CPU, at least one GPU (Graphics Processing Unit), at least one ASIC (Application Specific Integrated Circuit), at least one FPGA (Field Programmable Gate Array), or a combination thereof.

[0086] The processor 101 controls the operation of the control device 50 by executing various programs. The processor 101 reads out programs to be executed from the auxiliary storage device 120 or the ROM 102 to the RAM 103 upon receiving execution instructions for various programs. The RAM 103 functions as a working memory and temporarily stores various types of data necessary for program execution.

[0087] A LAN (Local Area Network), an antenna, and the like are connected to the communication interface 104. The control device 50 exchanges data with an external device via the communication interface 104. The external device includes, for example, a server.

[0088] The above-described display unit 14 (see FIG. 3) is connected to the display interface 105. The display interface 105 sends an image signal for displaying an image to display unit 14 according to a command from the processor 101 or the like. The display unit 14 is, for example, a liquid crystal display, an organic EL (Electro Luminescence) display, or other display. Note that the display unit 14 may also be formed in one piece with the control device 50 or may be formed separately from the control device 50.

[0089] The input device 108 is connected to the input interface 107. The input device 108 is, for example, a mouse, keyboard, touch panel, or other device capable of accepting user operations. Note that the input device 108 may be formed in one piece with the control device 50 or may be formed separately from the control device 50.

[0090] The auxiliary storage device 120 is, for example, a storage medium such as a hard disk, a flash memory, and an SSD. The auxiliary storage device 120 stores, for example, a training data set 122, the above-described conversion model 124, a training program 126, and a tension abnormality detection program 128. The storage location for these is not limited to the auxiliary storage device 120, and they may also be stored in a storage region of the processor 101 (e.g., cache memory, etc.), the ROM 102, the RAM 103, an external device (e.g., a server), or the like.

[0091] The training program 126 is a program for generating the conversion model 124 using the training data set 122. The training program 126 may also be provided as part of any program, instead of as a standalone pro-

gram. In this case, the training processing performed by the training program 126 is realized in cooperation with any program. Even if a program does not include some of these modules, the program does not deviate from the gist of the training program 126 according to the present embodiment. Furthermore, some or all of the functions provided by the training program 126 may also be realized by dedicated hardware. Furthermore, the control device 50 may be included in the form of a so-called cloud service in which at least one server executes some of the processing of the training program 126.

[0092] The tension abnormality detection program 128 is a program for detecting abnormality in the tension of the thread wound by the thread winding machine 1, using the trained conversion model 124. The tension abnormality detection program 128 may also be provided as a part of any program, instead of as a standalone program. In this case, the abnormality detection processing performed by the tension abnormality detection program 128 is realized in cooperation with any program. Even if a program does not include some of these modules, the program does not deviate from the gist of the tension abnormality detection program 128 according to the present embodiment. Furthermore, some or all of the functions provided by the tension abnormality detection program 128 may also be realized by dedicated hardware. Furthermore, the control device 50 may be included in the form of a so-called cloud service in which at least one server executes some of the processing of the tension abnormality detection program 128.

C. Training Data Set 122

[0093] Next, the training data set 122 shown in FIG. 9 will be described with reference to FIG. 10. FIG. 10 is a diagram showing an example of the training data set 122.

[0094] The training data set 122 includes a plurality of pieces of training data 123. The number of pieces of training data 123 included in the training data set 122 is set as appropriate. As an example, the number of pieces of training data 123 is several tens to hundreds of thousands.

[0095] In each piece of the training data 123, a data ID (Identification) and a tension waveform with normal tension are associated with each other. The data ID is information for uniquely identifying the training data 123. The data ID is, for example, input by a user so as not to be redundant.

[0096] The tension waveform defined by the training data 123 is a group of data in which tension detected by the above-described tension sensor 13 while the thread winding machine 1 winds the thread is arranged in chronological order. That is, in one piece of training data 123, a tension is associated with each time. The numbers of dimensions of the tension waveforms defined in the training data set 122 are equal to each other. Also, the training data set 122 is constituted by only the training data 123 for a normal tension waveform.

D. Functional Configuration of Control Device 50

[0097] Next, the functional configuration of the control device 50 will be described with reference to FIGS. 11 to 13. FIG. 11 is a diagram showing an example of the functional configuration of the control device 50.

[0098] As shown in FIG. 11, the control device 50 includes a training unit 50b and a detection unit 50c as functional configurations. These functional configurations will be described in order below.

D1. Training Unit 50b

[0099] First, the function of the training unit 50b shown in FIG. 11 will be described with reference to FIG. 12. FIG. 12 is a diagram conceptually showing the training processing performed by the training unit 50b.

[0100] The training unit 50b performs training processing using the above-described training data set 122 (see FIG. 10) to generate a conversion model 124 serving as an autoencoder. A machine learning algorithm adopted for the training processing is not particularly limited, and for example, a neural network such as deep learning or the like can be adopted. Training processing using a neural network will be described below.

[0101] As shown in FIG. 12, the conversion model 124 is constituted by an input layer X, an intermediate layer H, and an output layer Y.

[0102] The input layer X is configured to receive input of a normal tension waveform defined in the training data 123. The input layer X is composed of, for example, N units x_1 to x_N (N is a natural number). The number of units constituting the input layer X is the same as the number of dimensions of the input tension waveform. For example, if the input tension waveform is N-dimensional data, the input layer X is constituted by N units. Each unit constituting the input layer X outputs input data to each unit of the first layer of the intermediate layer H.

[0103] The intermediate layer H is constituted by one layer or a plurality of layers. In the example of FIG. 12, the intermediate layer H is constituted by L layers (L is a natural number). Each layer of the intermediate layer H includes a plurality of units. The number of units in each layer of the intermediate layer H may be the same or different. In the example of FIG. 12, the first layer of the intermediate layer H is constituted by Q units h_{A1} to h_{AQ} (Q is a natural number). Also, the final layer of the intermediate layer H is constituted by R units h_{L1} to h_{LR} (R is a natural number).

[0104] Each unit constituting each layer of the intermediate layer H is connected to each unit of the previous layer and each unit of the next layer. Each unit in each layer receives an output value from each unit in the previous layer, multiplies each output value by a weight, accumulates the multiplication results, adds (or subtracts) a predetermined bias to (or from) the accumulation result, inputs the addition result (or subtraction result) to a predetermined function (e.g., a sigmoid function), and out-

puts the output value of the function to each unit in the next layer.

[0105] In the conversion model 124 serving as an autoencoder, the number of units constituting each layer of the intermediate layer H is smaller than the number of units constituting the input layer X. As a result, the number of dimensions of the tension waveform is compressed in the process of being transferred from the input layer X to the intermediate layer H.

[0106] The output layer Y is configured to restore the tension waveform compressed in the intermediate layer H. More specifically, the output layer Y is constituted by the same number of units as the input layer X. As an example, if the input layer X is constituted by N units, the output layer Y is constituted by N units. In the example of FIG. 12, the output layer Y is constituted by N units y_1 to y_N . Hereinafter, the units y_1 to y_N are also referred to as units y.

[0107] Each of the units y is connected to each of the units h_{L1} to h_{LR} in the final layer of the intermediate layer H. Each of the units y receives an output value from each of the units in the final layer of the intermediate layer H, multiplies each output value by a weight, accumulates the multiplication results, adds (or subtracts) a predetermined bias to (or from) the accumulation result, inputs the addition result (or subtraction result) to a predetermined function (e.g., a sigmoid function), and outputs the output result of the function as an output value.

[0108] Next, processing for updating internal parameters of the conversion model 124 by the training unit 50b will be described.

[0109] The training unit 50b inputs a normal tension waveform $T(t)$ defined in the first piece of training data 123 to the conversion model 124. As a result, the conversion model 124 compresses the tension waveform $T(t)$ and restores the tension waveform $T(t)$ to a tension waveform $T'(t)$ of the same dimension. Next, the training unit 50b calculates an error "Z" between the input tension waveform $T(t)$ and the output tension waveform $T'(t)$. As an example, the error "Z" is calculated based on the following formula (1).

$$Z = \{(T(t_1) - T'(t_1))^2 + \dots + (T(t_N) - T'(t_N))^2\} / N \quad \dots (1)$$

[0110] Next, the training unit 50b updates the internal parameters (e.g., weight and bias) of the conversion model 124 such that the error "Z" becomes smaller. The updating of the internal parameters is realized through, for example, error backpropagation.

[0111] The training unit 50b repeatedly updates the internal parameters of the conversion model 124 for each piece of training data 123 included in the training data set 122. As a result, the conversion model 124 is trained to compress the normal tension waveform and then restore the normal tension waveform. That is, if a normal tension waveform is input, the conversion model 124 outputs a tension waveform similar to the normal tension

waveform, and if an abnormal tension waveform is input, the conversion model 124 outputs a tension waveform different from the abnormal tension waveform. Stated differently, the conversion model 124 functions like a sort of filter that allows normal tension waveforms to pass but does not allow abnormal tension waveforms to pass.

[0112] Note that the training unit 50b does not need to use all of the training data 123 included in the training data set 122 for the training processing, and may use some of the training data 123 included in the training data set 122 to generate the conversion model 124. The rest of the training data 123 is used, for example, for evaluation of the conversion model 124 and the like.

D2. Detection Unit 50c

[0113] Next, functions of the detection unit 50c shown in FIG. 11 will be described with reference to FIG. 13. FIG. 13 is a diagram conceptually showing abnormality detection processing performed by the detection unit 50c.

[0114] The detection unit 50c detects abnormality in the tension of the thread wound by the thread winding machine 1 based on the degree of similarity between the input tension waveform obtained from the tension sensor 13 and the output tension waveform obtained by inputting the input tension waveform to the conversion model 124.

[0115] More specifically, first, the detection unit 50c inputs the input tension waveform obtained from the tension sensor 13 to the conversion model 124 and acquires the output tension waveform from the conversion model 124. The acquisition destination of the conversion model 124 may be the storage unit 50d described above, or may be an external device. If a normal tension waveform is input, the conversion model 124 outputs a tension waveform similar to the normal tension waveform, and if an abnormal tension waveform is input, the conversion model 124 outputs a tension waveform different from the abnormal tension waveform. The detection unit 50c detects abnormality in the tension of the thread wound by the thread winding machine 1 based on the degree of similarity between the input tension waveform and the output tension waveform. Since the function of the detection unit 50c is as described above, detailed description of the function will not be repeated.

E. Modified Example 1

[0116] Next, a modified example relating to the functional arrangement of the thread winding machine 1 will be described with reference to FIG. 14.

[0117] In the example of FIG. 11 described above, the training unit 50b and the detection unit 50c were provided in the same thread winding machine 1. However, the training unit 50b and the detection unit 50c do not necessarily need to be provided in the same thread winding machine 1. As an example, the training unit 50b may also be provided in a different device.

[0118] FIG. 14 is a diagram showing an example of the

device configuration of an abnormality detection system 500 according to this modified example. As shown in FIG. 14, the abnormality detection system 500 includes one or more thread winding machines 1 and one or more information processing devices 200. In the example of FIG. 14, the abnormality detection system 500 is constituted by three thread winding machines 1A to 1C and one information processing device 200.

[0119] The thread winding machines 1A to 1C and the information processing device 200 are connected to the same network NW and are configured to be able to communicate with each other. The thread winding machines 1 and the information processing device 200 may also be communicatively connected by wire or wirelessly.

[0120] The information processing device 200 is a desktop personal computer, a notebook personal computer, a tablet terminal, or another information processing terminal.

[0121] In the example of FIG. 14, the training unit 50b is provided in the information processing device 200. Also, the detection unit 50c is provided in the thread winding machine 1C.

[0122] The information processing device 200 collects the above-described training data 123 (see FIG. 10) from the thread winding machines 1 (e.g., the thread winding machines 1A and 1B) connected to the network NW. Next, the training unit 50b of the information processing device 200 executes training processing using the training data 123 collected from all of the thread winding machines 1, and generates the above-described conversion model 124. Since the training function of the training unit 50b is as described above, description thereof will not be repeated.

[0123] Thereafter, the information processing device 200 transmits the generated conversion model 124 to the thread winding machine 1 (e.g., the thread winding machine 1C). The detection unit 50c of the thread winding machine 1C uses the conversion model 124 to detect tension abnormalities generated in the thread winding machine 1C. Since the abnormality detection function of the detection unit 50c is as described above, description thereof will not be repeated.

F. Modified Example 2

F1. Overview

[0124] Next, the tension abnormality detection device 10 according to a modified example will be described with reference to FIGS. 15 to 18.

[0125] In the above example, the tension abnormality detection device 10 determines whether or not abnormality of tension has occurred by inputting the input tension waveform obtained from the tension sensor 13 to the conversion model 124. On the other hand, the tension abnormality detection device 10 according to the present modified example further identifies the type of the tension abnormality that has occurred if it is determined that a

tension abnormality has occurred. Note that other points such as the hardware configuration of the tension abnormality detection device 10 are as described above, and therefore description thereof will not be repeated.

F2. Training Data Set 132

[0126] Next, a training data set 132 used when generating a conversion model for identifying the type of tension abnormality will be described with reference to FIG. 15. FIG. 15 is a diagram showing an example of the training data set 132.

[0127] The training data set 132 includes a plurality of pieces of training data 133. The number of pieces of training data 133 included in the training data set 132 is set as appropriate. As an example, the number of pieces of training data 133 is several tens to several hundreds of thousands.

[0128] In each piece of the training data 133, a data ID (Identification), a tension waveform with abnormal tension, and a type of abnormal tension are associated. A data ID is information for uniquely identifying the training data 133. The data ID is input by the user, for example, so as not to be redundant.

[0129] The tension waveform defined in the training data 133 is a data group in which the tension detected by the above-described tension sensor 13 while the thread winding machine 1 winds the thread is arranged chronologically. The numbers of the dimensions of the tension waveforms defined in the training data set 132 are equal to each other. Also, each tension waveform is associated with an abnormality type as a label. The abnormality type is input by the user via, for example, the input device 108 described above, or the like.

F3. Functional Configuration of Control Device 50

[0130] Next, the functional configuration of the control device 50 in this modified example will be described with reference to FIGS. 16 to 18. FIG. 16 is a diagram showing an example of the functional configuration of the control device 50.

[0131] The control device 50 includes a training unit 50b, a detection unit 50c, a training unit 50e, and an identification unit 50f as functional configurations. The control device 50 shown in FIG. 16 is different from the control device 50 shown in FIG. 11 in that it further includes the training unit 50e and the identification unit 50f. Since the functional descriptions of the training unit 50b and the detection unit 50c are as described above, the description thereof will not be repeated. Hereinafter, the functions of the training unit 50e and the identification unit 50f will be described in order below.

[0132] Note that it is not necessary to provide all of the training unit 50b, the detection unit 50c, the training unit 50e, and the identification unit 50f in the control device 50. As an example, at least one of the training unit 50b and the training unit 50e may be provided in the informa-

tion processing device 200 described above.

(a) Training Unit 50e

[0133] First, the function of the training unit 50e shown in FIG. 16 will be described with reference to FIG. 17. FIG. 17 is a diagram conceptually showing training processing performed by the training unit 50e.

[0134] The training unit 50e executes training processing using the above-described training data set 132 (see FIG. 15), and generates an estimation model 134 for identifying a tension abnormality. A machine learning algorithm employed for training processing is not particularly limited, and for example, various machine learning algorithms, such as a neural network such as deep learning, a support vector machine, or a decision tree system, can be employed thereas. Hereinafter, training processing using deep learning will be described.

[0135] As shown in FIG. 17, the estimation model 134 is constituted by an input layer X, an intermediate layer H, and an output layer Y.

[0136] The input layer X is configured to receive input of an abnormal tension waveform defined in the training data 133. The input layer X is constituted by, for example, N units x_1 to x_N (N is a natural number). The number of units constituting the input layer X is the same as the number of dimensions of the input tension waveform. For example, if the input tension waveform is data of N dimensions, the input layer X is constituted by N units. Each unit constituting the input layer X outputs input data to each unit of the first layer of the intermediate layer H.

[0137] The intermediate layer H is constituted by one layer or a plurality of layers. In the example of FIG. 17, the intermediate layer H is constituted by L layers (L is a natural number). Each layer of the intermediate layer H includes a plurality of units. The number of units in each layer of the intermediate layer H may be the same or different. In FIG. 17, the first layer of the intermediate layer H is constituted by Q units h_{A1} to h_{AQ} (Q is a natural number). Also, the final layer of the intermediate layer H is constituted by R units h_{L1} to h_{LR} (R is a natural number).

[0138] Each unit constituting each layer of the intermediate layer H is connected to each unit of the previous layer and each unit of the next layer. Each unit in each layer receives an output value from each unit in the previous layer, multiplies the output value by a weight, accumulates the multiplication results, adds (or subtracts) a predetermined bias to (or from) the accumulation result, inputs the addition result (or subtraction result) to a predetermined function (e.g., a sigmoid function), and outputs the output value of the function to each unit of the next layer.

[0139] The output layer Y outputs an estimation result corresponding to the input tension waveform. The output layer Y is constituted by units y_1 to y_3 , for example. Hereinafter, the units y_1 to y_3 are also referred to as units y.

[0140] Each of the units y is connected to the units h_{L1} to h_{LR} in the final layer of the intermediate layer H. Each

unit y receives an output value from each unit of the final layer of the intermediate layer H, multiplies each output value by a weight, integrates the multiplication results, adds (or subtracts) a predetermined bias to (or from) the integration result, inputs the addition result (or subtraction result) to a predetermined function (e.g., a sigmoid function), and outputs the output result of the function as an output value.

[0141] The number of units constituting the output layer Y is determined according to the number of types of tension abnormalities defined in the training data 133. As an example, in the case of detecting tension abnormalities "A" to "C", the number of units constituting the output layer Y is three, namely the units y_1 to y_3 . In this case, the unit y_1 is configured to output a score "sa" that indicates the likelihood that the tension abnormality "A" has occurred. The unit y_2 is configured to output a score "sb" indicating the likelihood that the tension abnormality "B" has occurred. The unit y_3 is configured to output a score "sc" indicating the likelihood that the tension abnormality "C" has occurred.

[0142] Note that in the example of FIG. 17, the estimation model 134 is configured to output a plurality of scores, but one estimation model may also be configured to output one score. As an example, a first estimation model may be configured to output a score "sa" for an abnormality type "A", a second estimation model may be configured to output a score "sb" for an abnormality type "B", and a third estimation model may be configured to output a score "sc" for an abnormality type "C".

[0143] Next, processing for updating the internal parameters of the estimation model 134 by the training unit 50e will be described.

[0144] The training unit 50e inputs a tension waveform T(t) defined in the first piece of training data 133 to the estimation model 134. Next, the training unit 50e obtains the estimation results "sa" to "sc" output from the estimation model 134 and correct answer scores "sa'" to "sc'" corresponding to the abnormality type associated with the first piece of training data 133.

[0145] As an example, if the abnormality type associated with the training data 133 is "A", the correct answer score is (sa', sb', sc')=(1,0,0). If the abnormality type associated with the training data 133 is "B", the correct answer score is (sa', sb', sc')=(0,1,0). If the abnormality type associated with the training data 133 is "C", the correct answer score is (sa', sb', sc')=(0,0,1).

[0146] The training unit 50e calculates an error "Z" between output results "sa" to "sc" of the estimation model 134 and the correct answer scores "sa'" to "sc'". The error "Z" is calculated, for example, based on the following formula (2).

$$Z=\{(sa-sa')^2+(sb-sb')^2+(sc-sc')^2\}/3 \quad \dots(2)$$

[0147] Next, the training unit 50e updates the various parameters (for example, weights and biases) included

in the estimation model 134 such that the error "Z" becomes smaller. Updating of the parameters is realized, for example, through the error backpropagation method.

[0148] The training unit 50e repeatedly updates the internal parameters of the estimation model 134 for each piece of training data 133 included in the training data set 132. As a result, the estimation model 134 outputs more accurate estimation results as training progresses.

[0149] Note that the training unit 50e does not need to use all of the training data 133 included in training data set 132 for training processing, and may use some of the training data 133 included in the training data set 132 to generate the estimation model 134. The remaining training data 133 is used, for example, for evaluation of the estimation model 134.

(b) Identification Unit 50f

[0150] Next, the function of the identification unit 50f shown in FIG. 16 will be described with reference to FIG. 18. FIG. 18 is a diagram conceptually showing processing for identifying an abnormality type, performed by the identification unit 50f.

[0151] First, the identification unit 50f acquires the estimation model 134 generated by the training unit 50e. The acquisition destination of the estimation model 134 may be the storage unit 50d described above, or may be an external device. If a tension abnormality is detected by the above-described detection unit 50c, the identification unit 50f identifies the type of tension abnormality that has occurred, based on the input tension waveform used for detecting the tension abnormality and the estimation model 134.

[0152] More specifically, the identification unit 50f inputs, to the estimation model 134, an input tension waveform indicating an abnormality. As a result, the estimation model 134 outputs a score indicating the likelihood that a tension abnormality has occurred, to the abnormality type. For example, as the estimation result, the estimation model 134 outputs a score "sa" indicating the likelihood that a tension abnormality "A" has occurred, a score "sb" indicating the likelihood that a tension abnormality "B" has occurred, and a score "sc" indicating the likelihood that a tension abnormality "C" has occurred.

[0153] The identification unit 50f identifies the type of tension abnormality that has occurred based on the scores "sa" to "sc". As an example, if any one of the scores "sa" to "sc" exceeds a predetermined threshold, the identification unit 50f outputs, as the identification result, the tension abnormality corresponding to the maximum score among the scores "sa" to "sc". On the other hand, if none of the scores "sa" to "sc" exceed the predetermined threshold, the identification unit 50f outputs that an unknown tension abnormality has occurred. The predetermined threshold may be pre-set or set as appropriate by the user.

[0154] Note that the output mode of the identification result by the identification unit 50f is not particularly lim-

ited. As an example, the identification unit 50f outputs a warning including the type of tension abnormality that has occurred. For example, the warning may be displayed as a message on the display unit 14 described above, may be output by voice, or may be stored in the storage unit 50d as a log.

G. Supplementary Notes

[0155] As described above, this embodiment includes the following disclosures.

[0156] According to an aspect of the present disclosure, a tension abnormality detection device having the following configuration is provided. That is, the tension abnormality detection device detects a degree of abnormality in tension of a thread wound by a thread winding machine. The tension abnormality detection device includes a tension sensor, a training unit, a storage unit, and a detection unit. The tension sensor detects the tension of the thread wound by the thread winding machine. The training unit that performs machine learning on a tension waveform with normal tension using an autoencoder to construct a conversion model that, based on a waveform with normal tension, generates the same waveform. The storage unit stores the conversion model constructed by the training unit. The detection unit generates an output tension waveform based on the conversion model and the input tension waveform based on the tension detected by the tension sensor, and detects a degree of abnormality in the tension of the thread wound by the thread winding machine based on a degree of similarity between the input tension waveform and the output tension waveform.

[0157] Since the tension waveform with normal tension is learned to create a conversion model, various abnormalities that deviate from normal tension can be detected. In particular, by constructing a model through machine learning of tension waveforms using an autoencoder, it is possible to detect abnormalities that cannot be detected with only the magnitude of the tension or the degree of change in the tension.

[0158] It is preferable that the tension abnormality detection device has the following configuration. That is, the thread winding machine winds the thread onto the bobbin while causing the thread to perform a traversing motion. The tension sensor detects tension by intermittently coming into contact with the thread according to the traversing motion of the thread.

[0159] The data detected by the tension sensor intermittently coming into contact with the thread includes not only the maximum value of the tension but also the change trend indicating how the tension changes with time. For this reason, since the tension waveform includes a large number of features, it is possible to create a model for accurately detecting the degree of abnormality in the tension of the thread.

[0160] In the tension abnormality detection device, it is preferable that the detection unit calculates a score

quantifying the degree of abnormality by comparing the input tension waveform and the output tension waveform.

[0161] This makes it possible to specifically obtain the degree of abnormality in the tension.

[0162] In the tension abnormality detection device, it is preferable that a threshold is set in advance in the detection unit, and the detection unit determines that the tension is abnormal if the score is greater than or equal to the threshold, and determines that the tension is normal if the score is less than the threshold.

[0163] This makes it possible to determine whether or not the tension is abnormal.

[0164] It is preferable that the tension abnormality detection device further includes a display unit, and the detection unit performs control for creating a graph showing the change in the score over time and displaying the graph on the display unit.

[0165] As a result, for example, an administrator or an operator can intuitively grasp the degree of abnormality in the tension.

[0166] In the tension abnormality detection device, it is preferable that the training unit and the detection unit detect the degree of abnormality in the tension of the thread being wound while the thread winding machine winds the thread.

[0167] As a result, the degree of abnormality in the tension can be detected in real time or at a timing close to real time. For this reason, for example, if the tension is abnormal, it is possible to perform processing such as interrupting the winding.

[0168] The embodiments disclosed herein are to be considered illustrative in all respects and not restrictive. The scope of the present invention is indicated not by the above description, but by the scope of the claims, and all modifications within the range and meaning equivalent to the scope of the claims are intended to be encompassed therein.

LIST OF REFERENCE NUMERALS

[0169]

1	Thread winding machine
10	Tension abnormality detection device
14	Display unit
13	Tension sensor
50	Control device
50b	Training unit
50c	Detection unit
50d	Storage unit
50f	Identification unit
124	Conversion model
134	Estimation model

Claims

1. A tension abnormality detection device (10), com-

prising:

a control device (50); and
a tension sensor (13) for detecting tension of a
thread wound by a thread winding machine (1),
wherein the control device (50) executes:

processing for acquiring an autoencoder
(124) trained to compress a normal tension
waveform and then restore the normal ten-
sion waveform; and
processing for detecting abnormality in the
tension of the thread wound by the thread
winding machine (1), based on a degree of
similarity between an input tension wave-
form obtained from the tension sensor (13)
and an output tension waveform obtained
by inputting the input tension waveform to
the autoencoder (124).

2. The tension abnormality detection device (10) ac-
cording to claim 1, wherein the control device (50)
further executes training processing for generating
the autoencoder (124) using a normal tension wave-
form.

3. The tension abnormality detection device (10) ac-
cording to claim 1 or 2,

wherein the thread winding machine (1) winds
thread on a bobbin while causing the thread to
perform a traversing motion, and
the tension sensor (13) is configured to detect
tension by intermittently coming into contact with
the thread according to the traversing motion of
the thread.

4. The tension abnormality detection device (10) ac-
cording to any one of claims 1 to 3,
wherein in the detecting processing,

abnormality of tension is detected if the degree
of similarity is greater than or equal to a prede-
termined threshold, and
normality of tension is detected if the degree of
similarity is less than the predetermined thresh-
old.

5. The tension abnormality detection device (10) ac-
cording to any one of claims 1 to 4,

wherein the tension abnormality detection de-
vice (10) further comprises a display unit (14),
and
the control device (50) further executes process-
ing for creating a graph showing change over
time in the degree of similarity and displaying
the graph on the display unit (14).

6. The tension abnormality detection device (10) ac-
cording to any one of claims 1 to 5, wherein the con-
trol device (50) executes the detecting processing
while the thread winding machine (1) winds the
thread.

7. The tension abnormality detection device (10) ac-
cording to any one of claims 1 to 6,
wherein the control device (50) further executes:

processing for acquiring an estimation model
trained to receive input of a tension waveform
and output a type of the abnormality; and
processing for, if abnormality of tension is de-
tected in the detecting processing, identifying
the type of the abnormality based on the input
tension waveform and the estimation model.

8. A tension abnormality detection method to be per-
formed by a tension abnormality detection device
(10),

wherein the tension abnormality detection de-
vice (10) includes a tension sensor (13) for de-
tecting tension of a thread wound by the thread
winding machine (1),
the tension abnormality detection method com-
prising:

a step of acquiring an autoencoder (124)
trained to compress a normal tension wave-
form and then restore the normal tension
waveform; and
a step of detecting abnormality in the ten-
sion of the thread wound by the thread wind-
ing machine (1), based on a degree of sim-
ilarity between an input tension waveform
obtained from the tension sensor (13) and
an output tension waveform obtained by in-
putting the input tension waveform to the
autoencoder (124).

9. A tension abnormality detection program to be ex-
cuted by a tension abnormality detection device (10),

wherein the tension abnormality detection de-
vice (10) includes a tension sensor (13) for de-
tecting tension of a thread wound by the thread
winding machine (1),
the tension abnormality detection program
causing the tension abnormality detection de-
vice (10) to execute:

a step of acquiring an autoencoder (124)
trained to compress a normal tension wave-
form and then restore the normal tension
waveform; and
a step of detecting abnormality in the ten-

sion of the thread wound by the thread winding machine (1), based on a degree of similarity between an input tension waveform obtained from the tension sensor (13) and an output tension waveform obtained by inputting the input tension waveform to the autoencoder (124).

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FIG.1

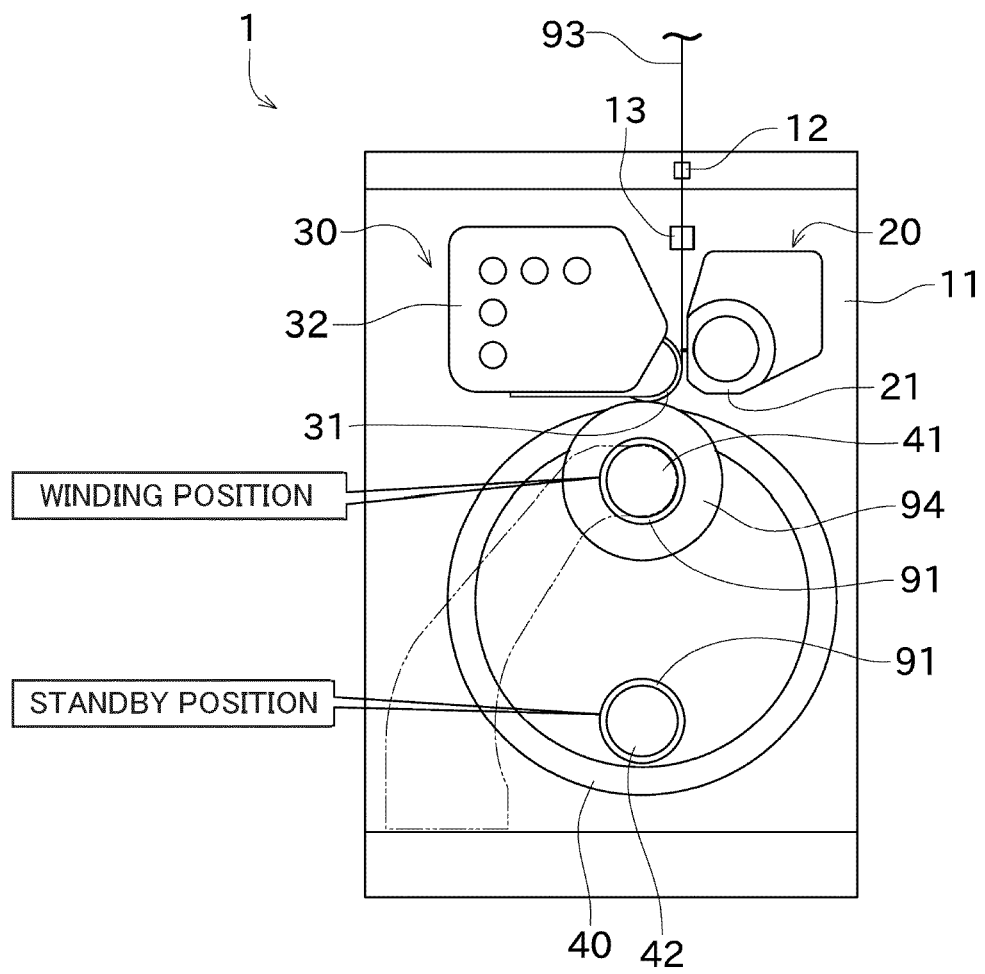


FIG.2

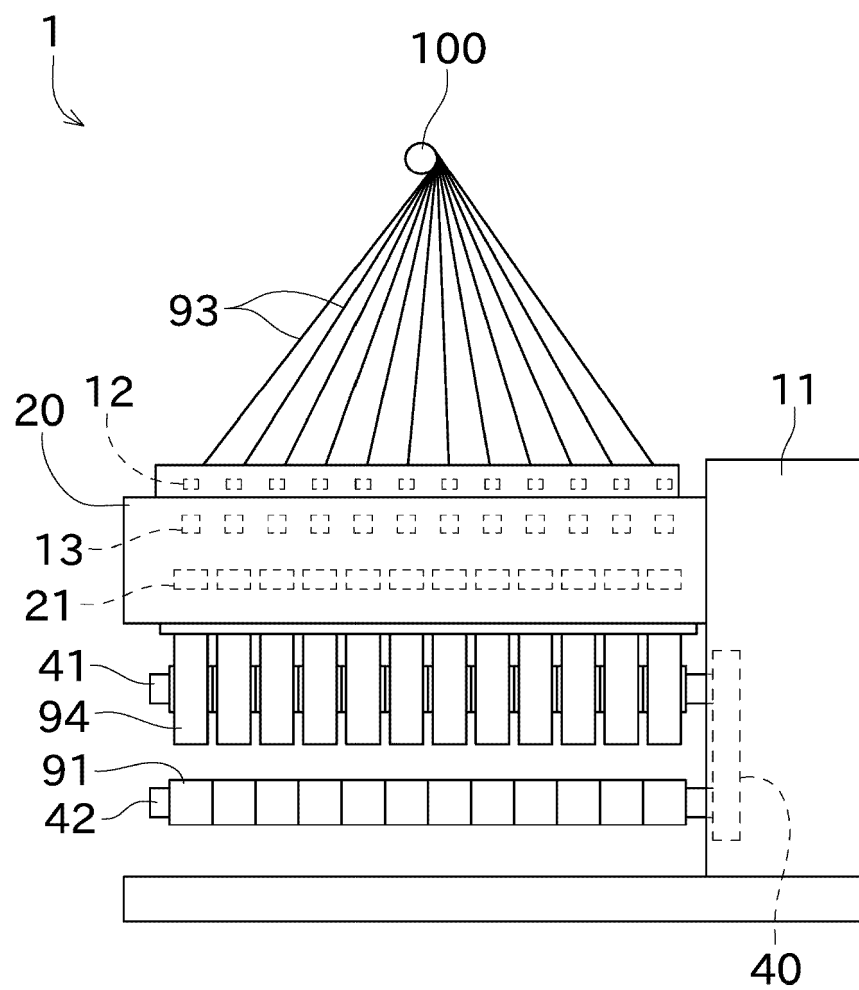


FIG.3

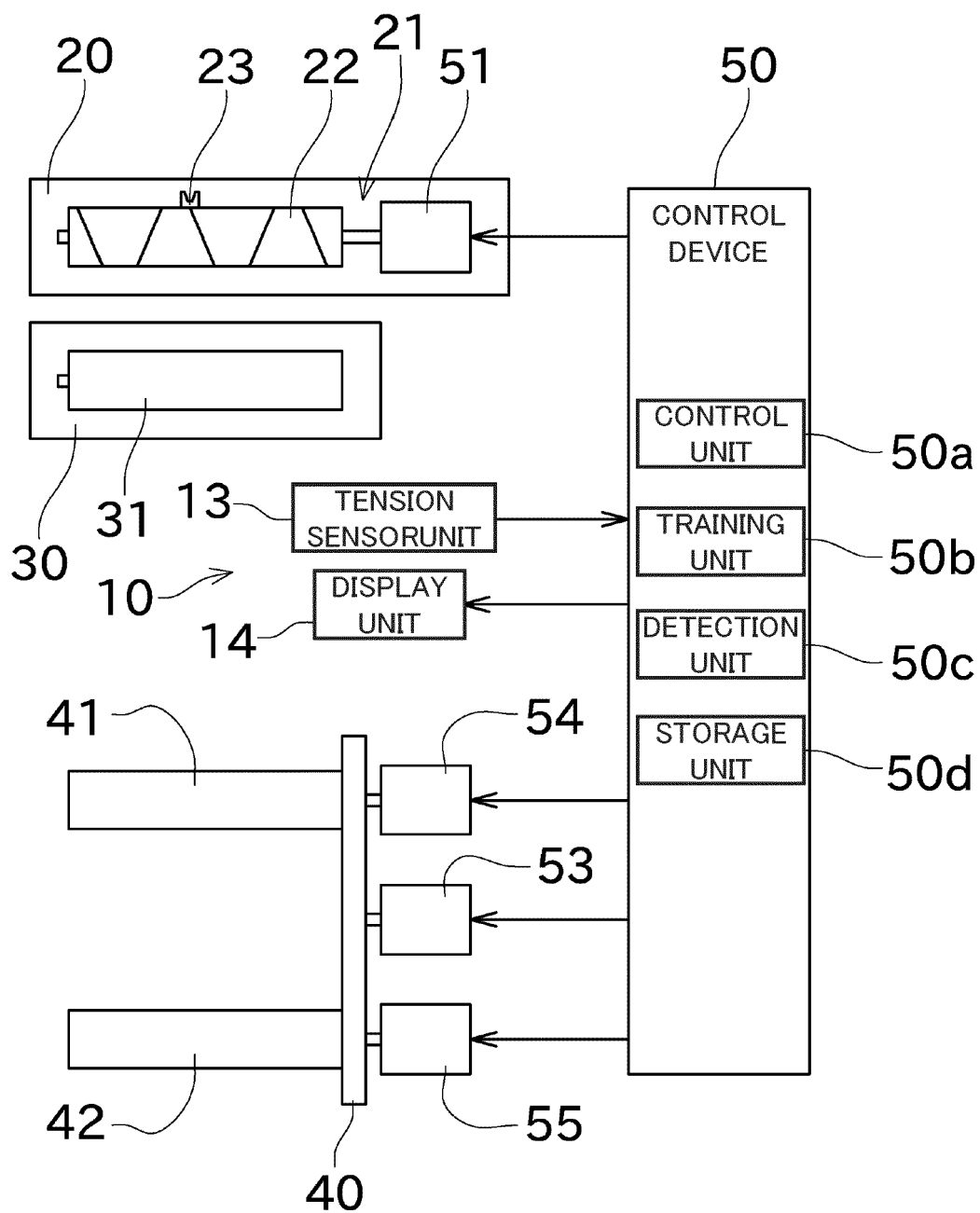


FIG.4

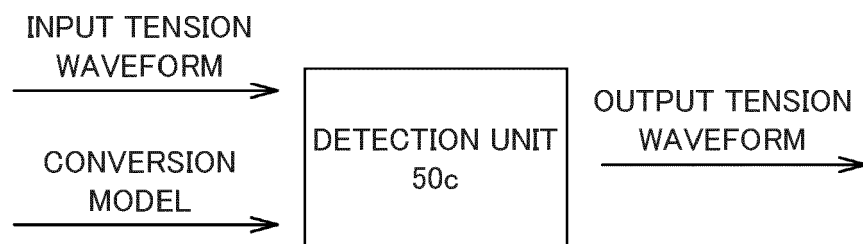


FIG.5

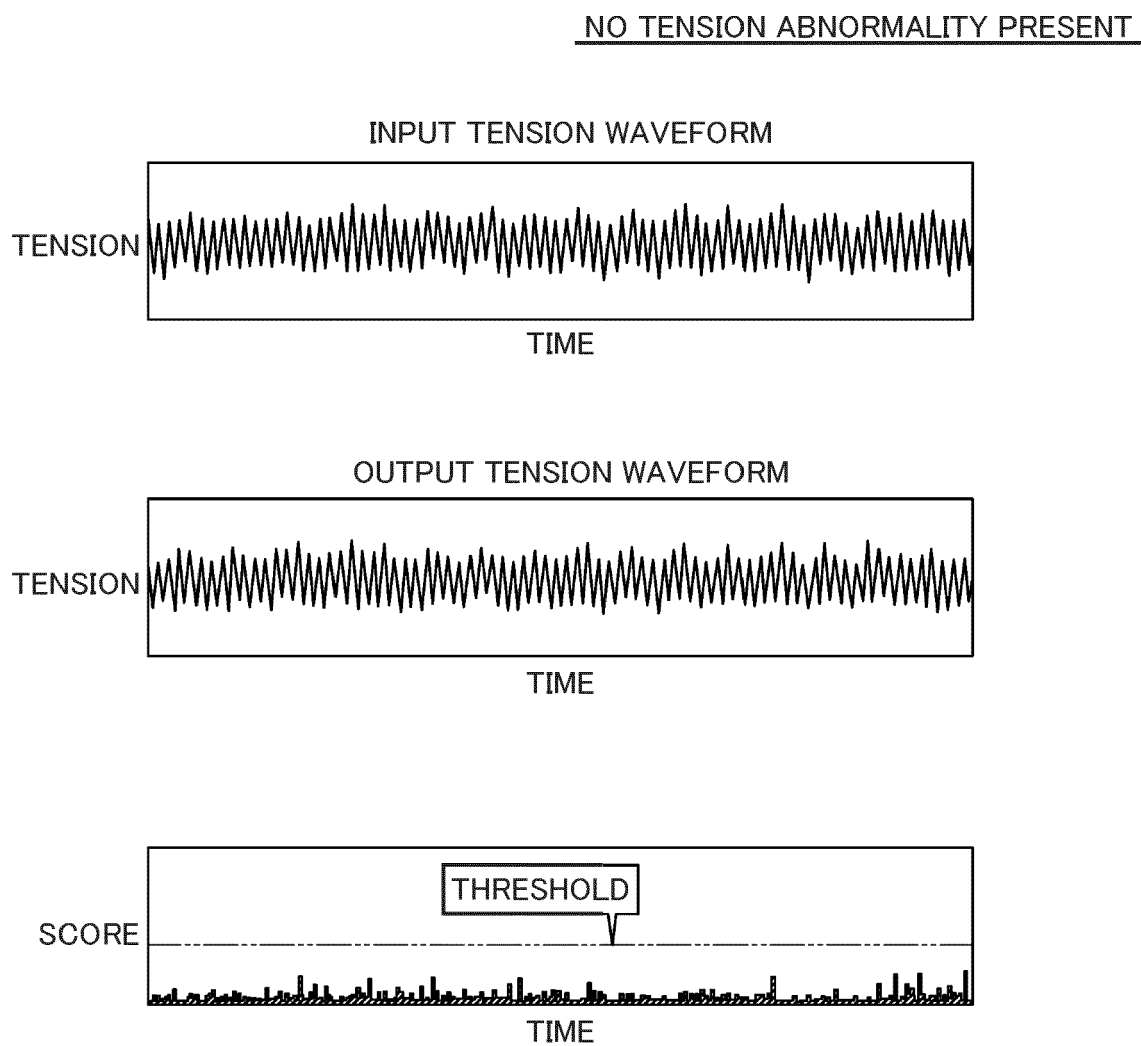


FIG.6

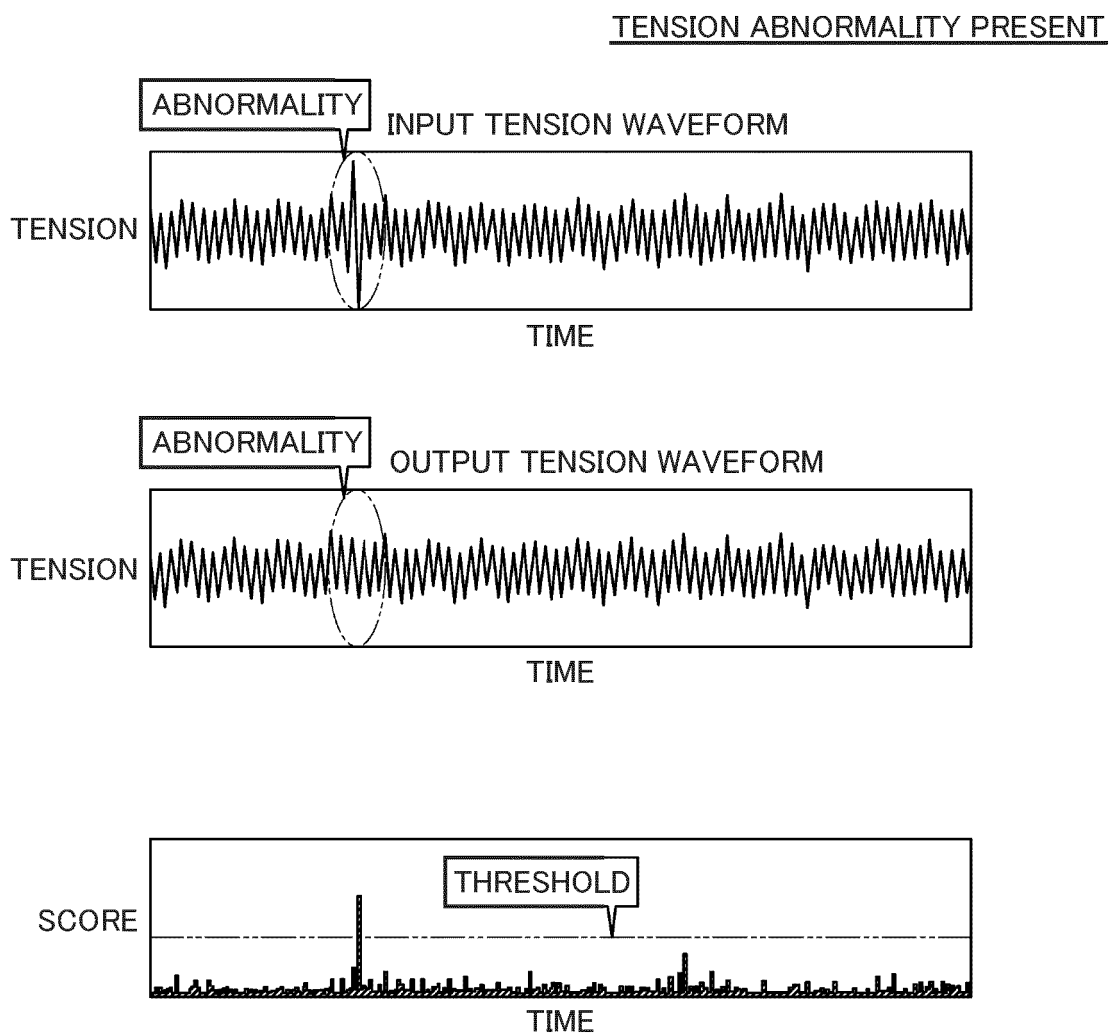


FIG.7

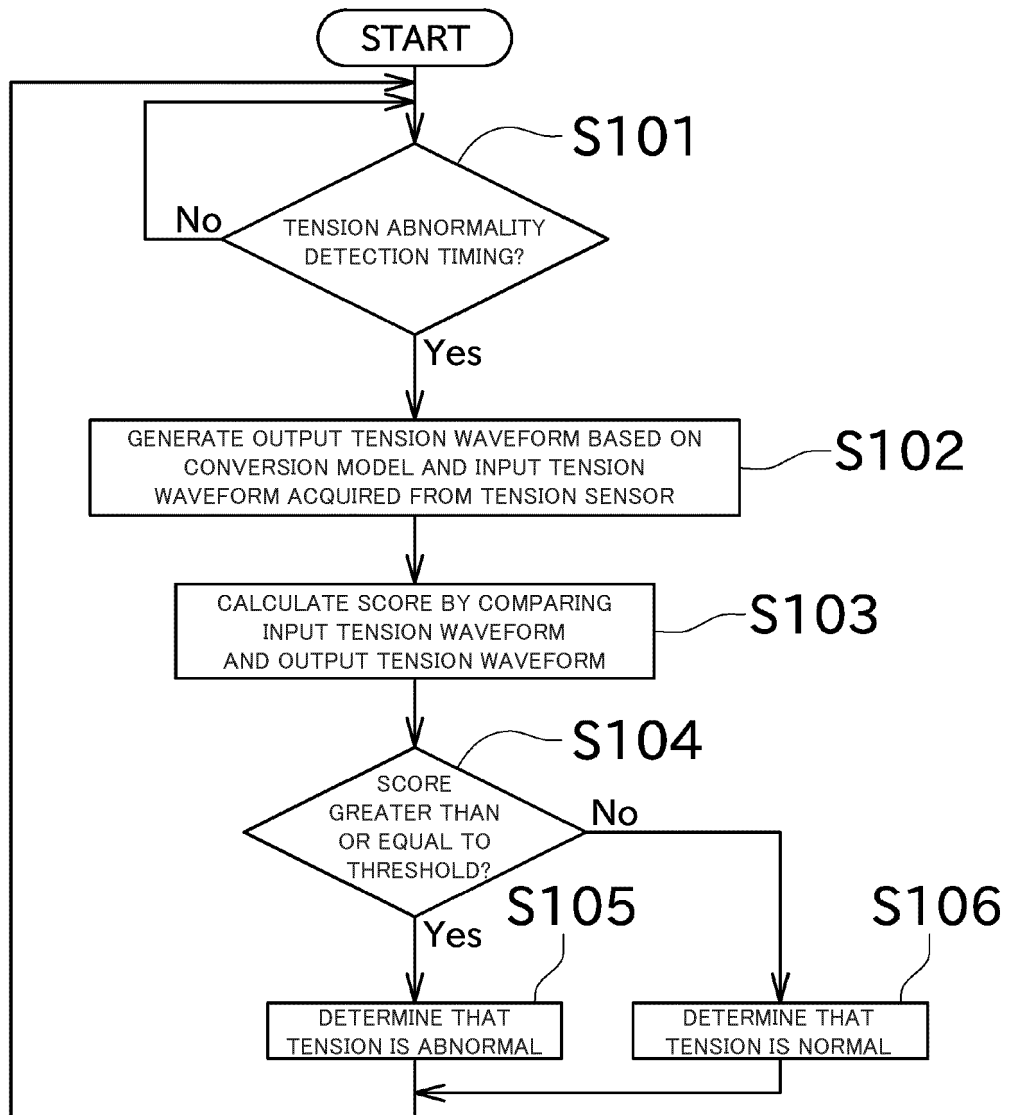


FIG.8

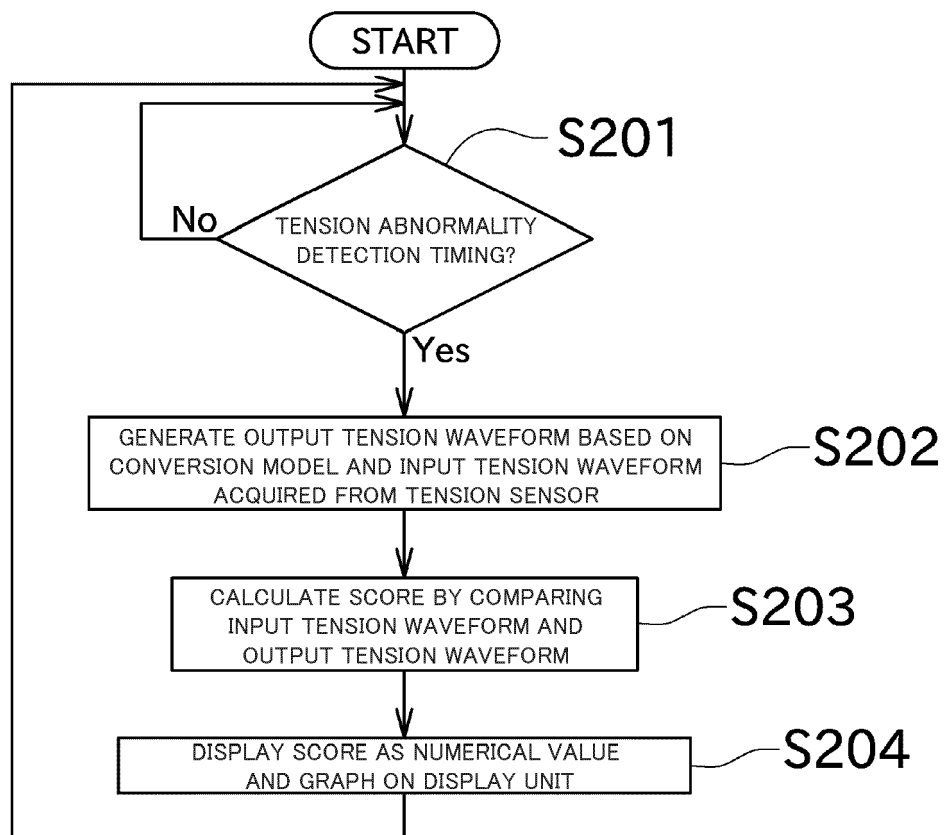


FIG.9

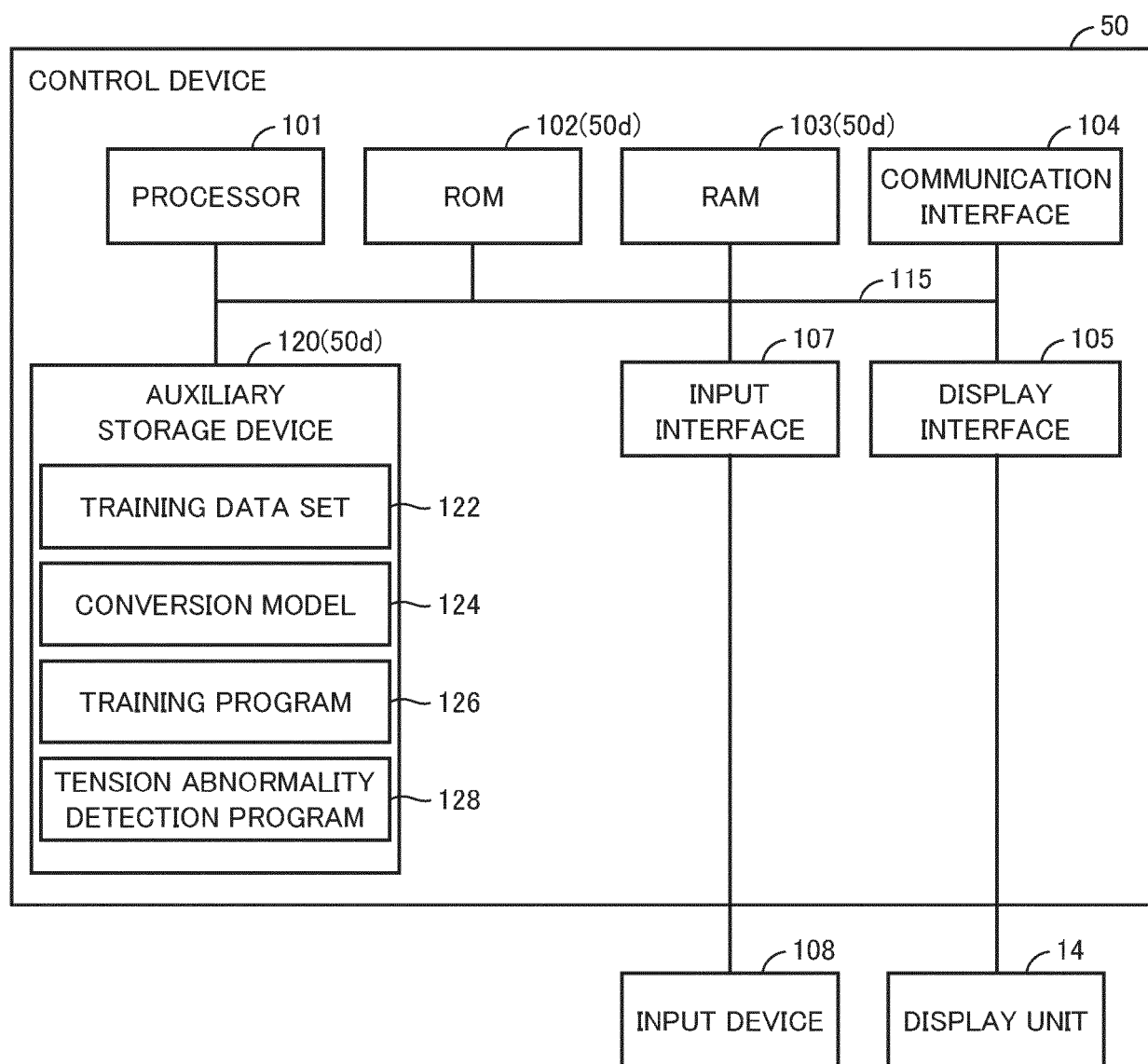


FIG.10

122

DATA ID	TENSION WAVEFORM
00001	$T_1(t)$
00002	$T_2(t)$
⋮	⋮

123

123

FIG.11

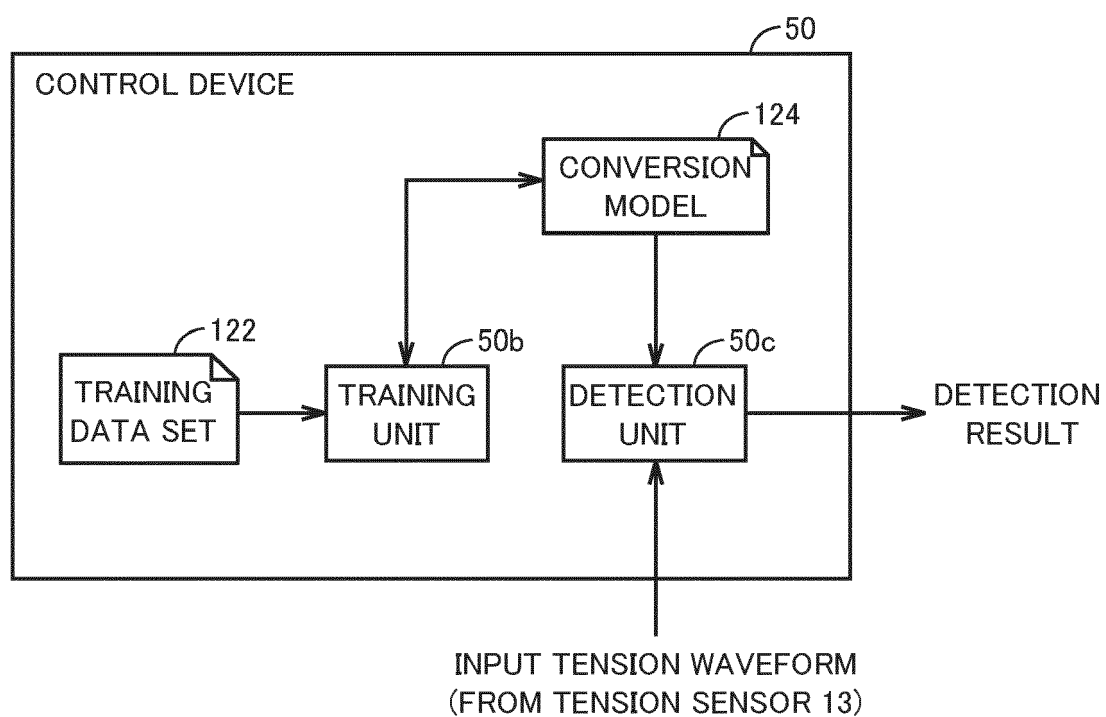


FIG.12

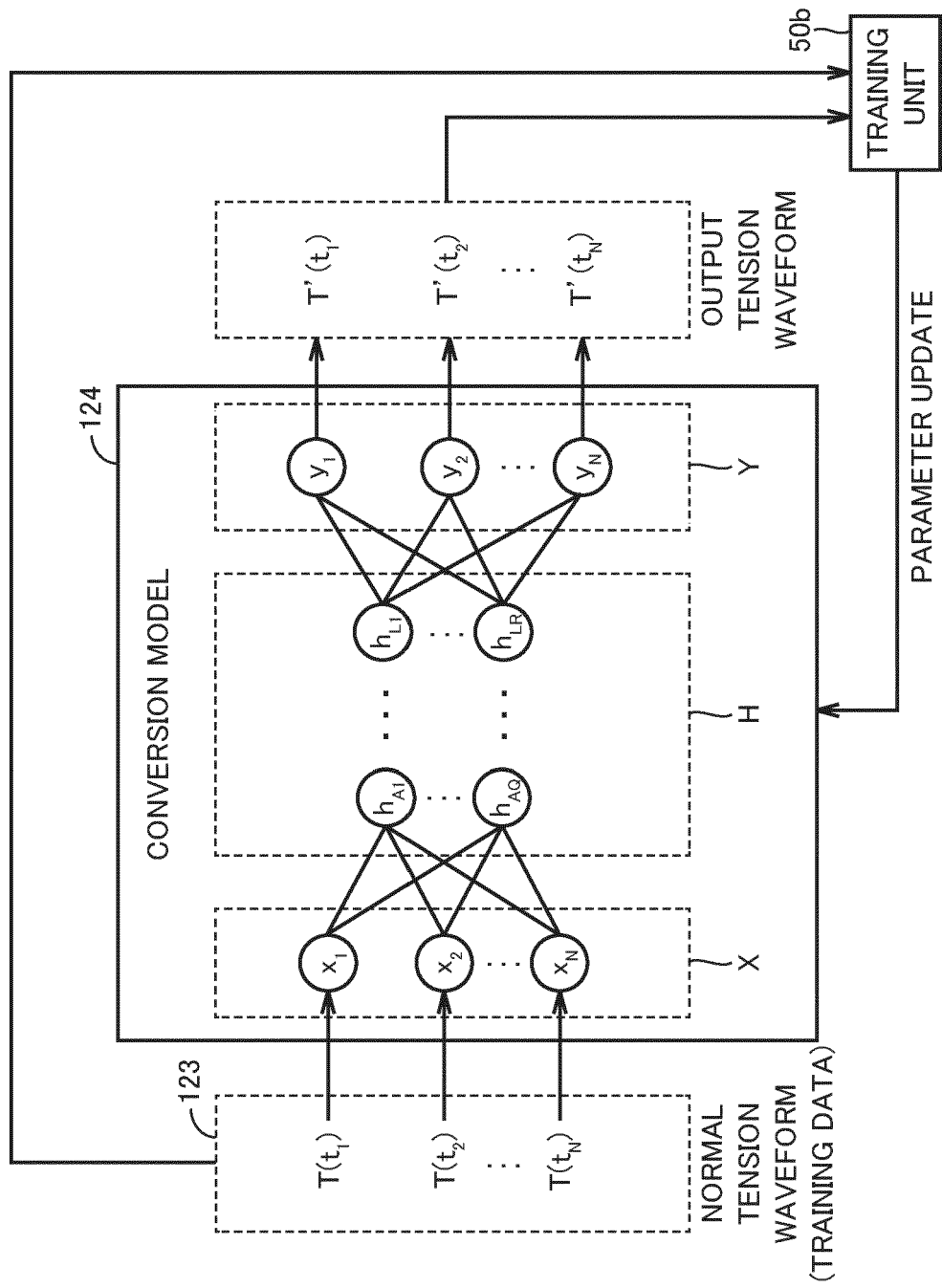


FIG.13

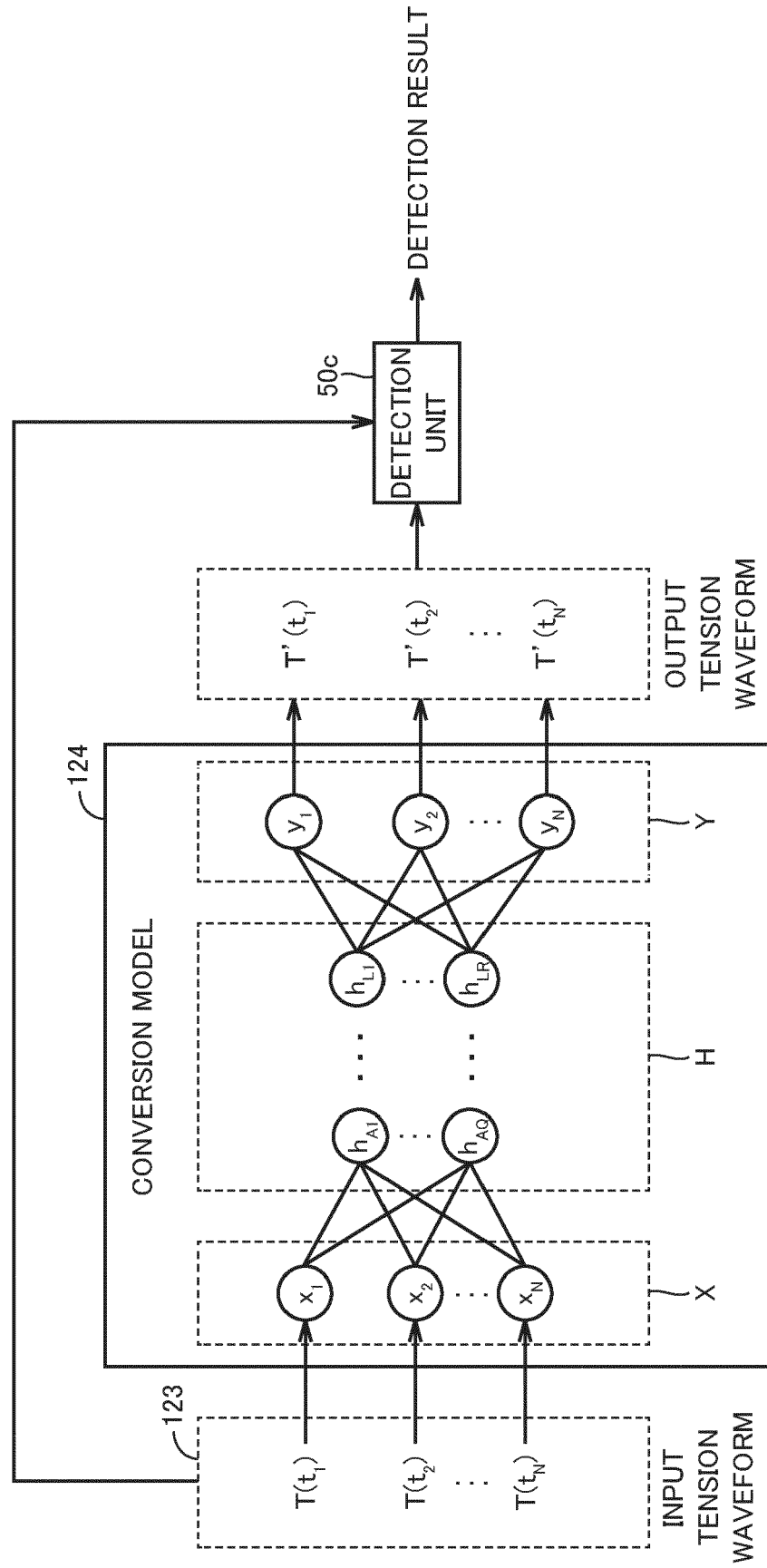


FIG.14

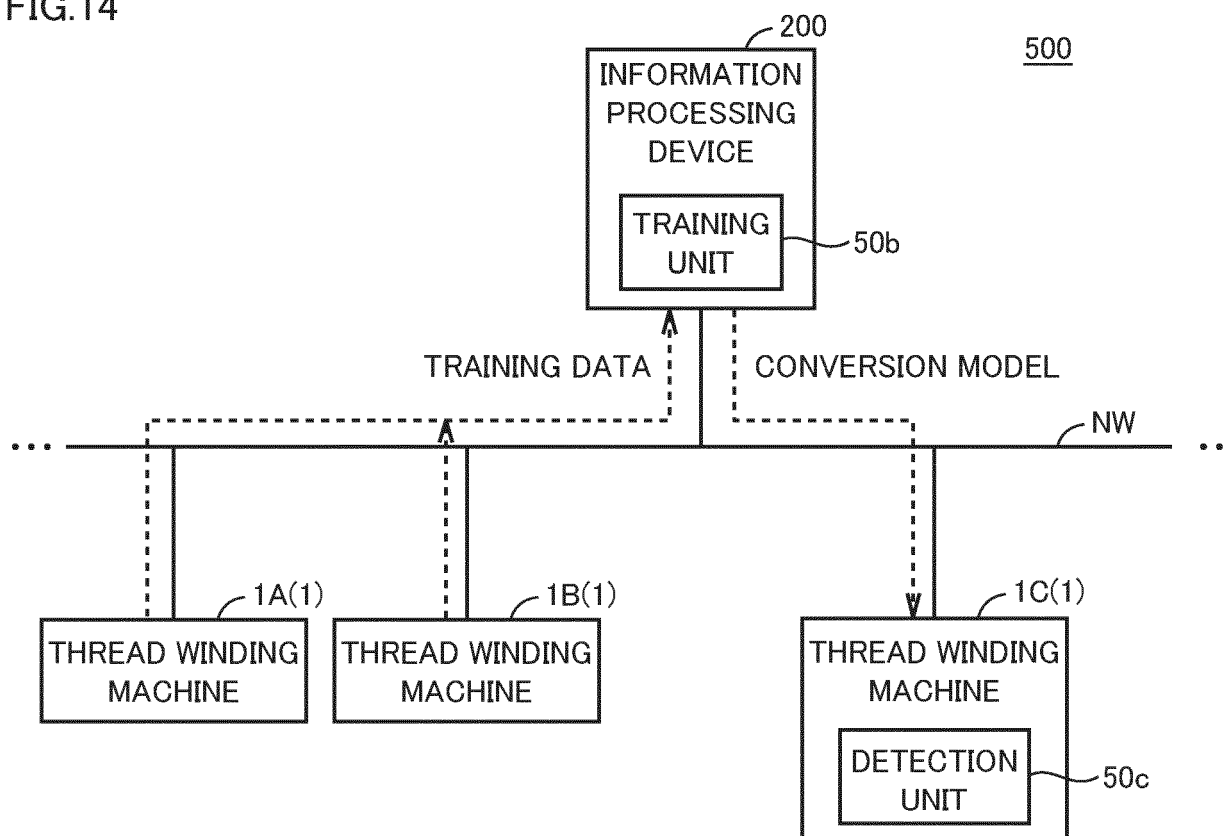


FIG.15

132

	DATA ID	TENSION WAVEFORM	ABNORMALITY TYPE
133	10001	$T_1(t)$	ABNORMALITY A
133	10002	$T_2(t)$	ABNORMALITY B
	⋮	⋮	⋮

FIG.16

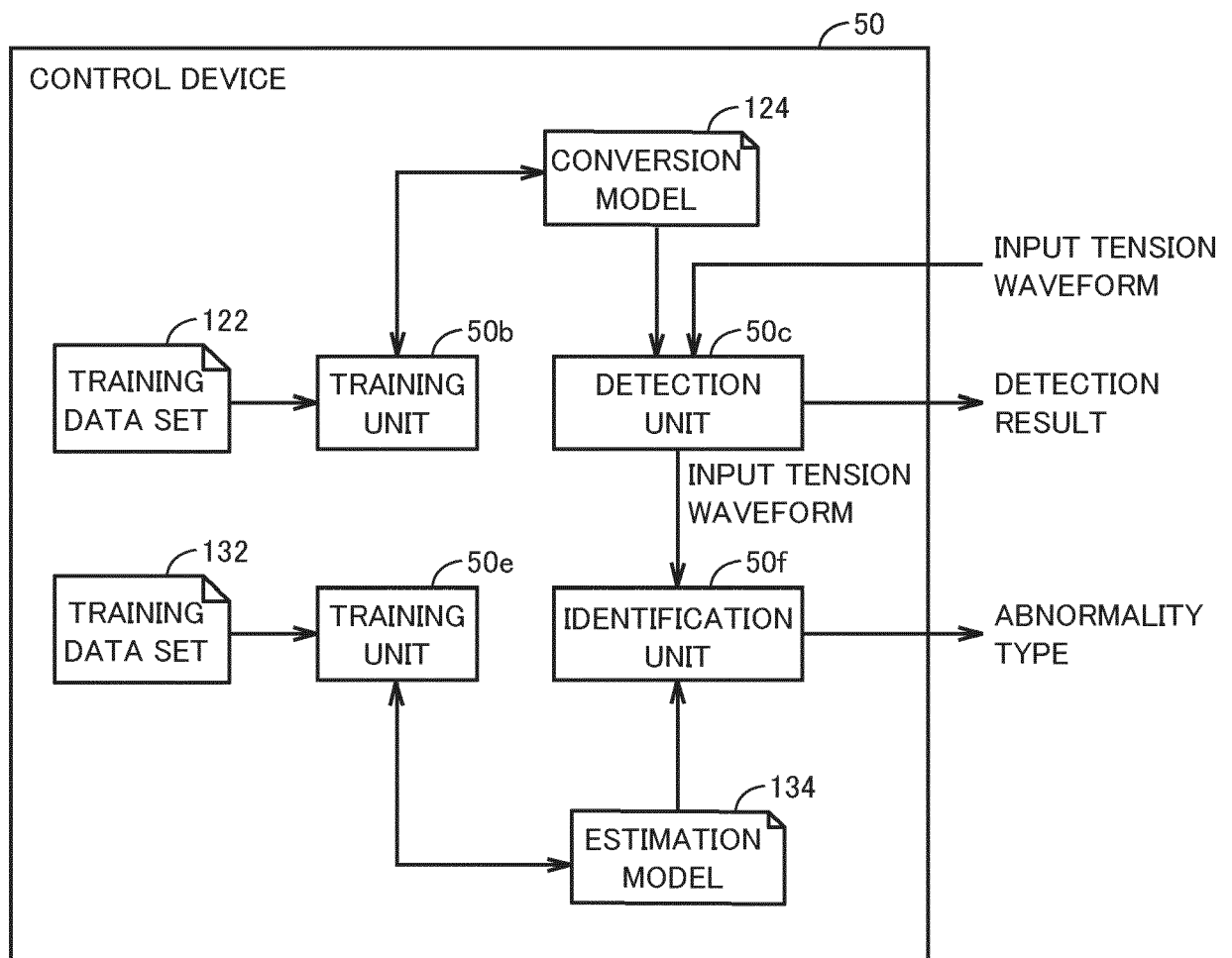


FIG.17

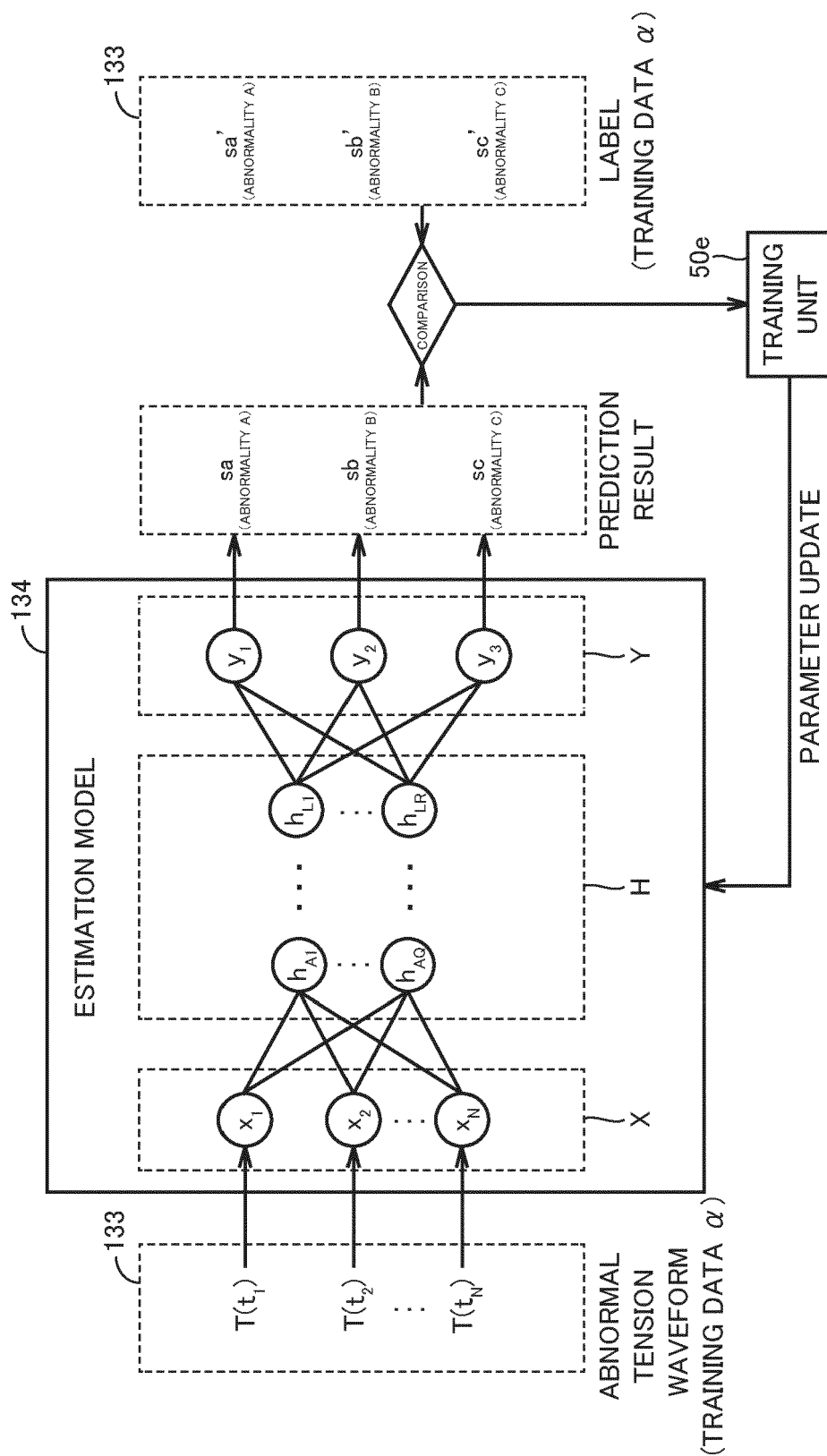
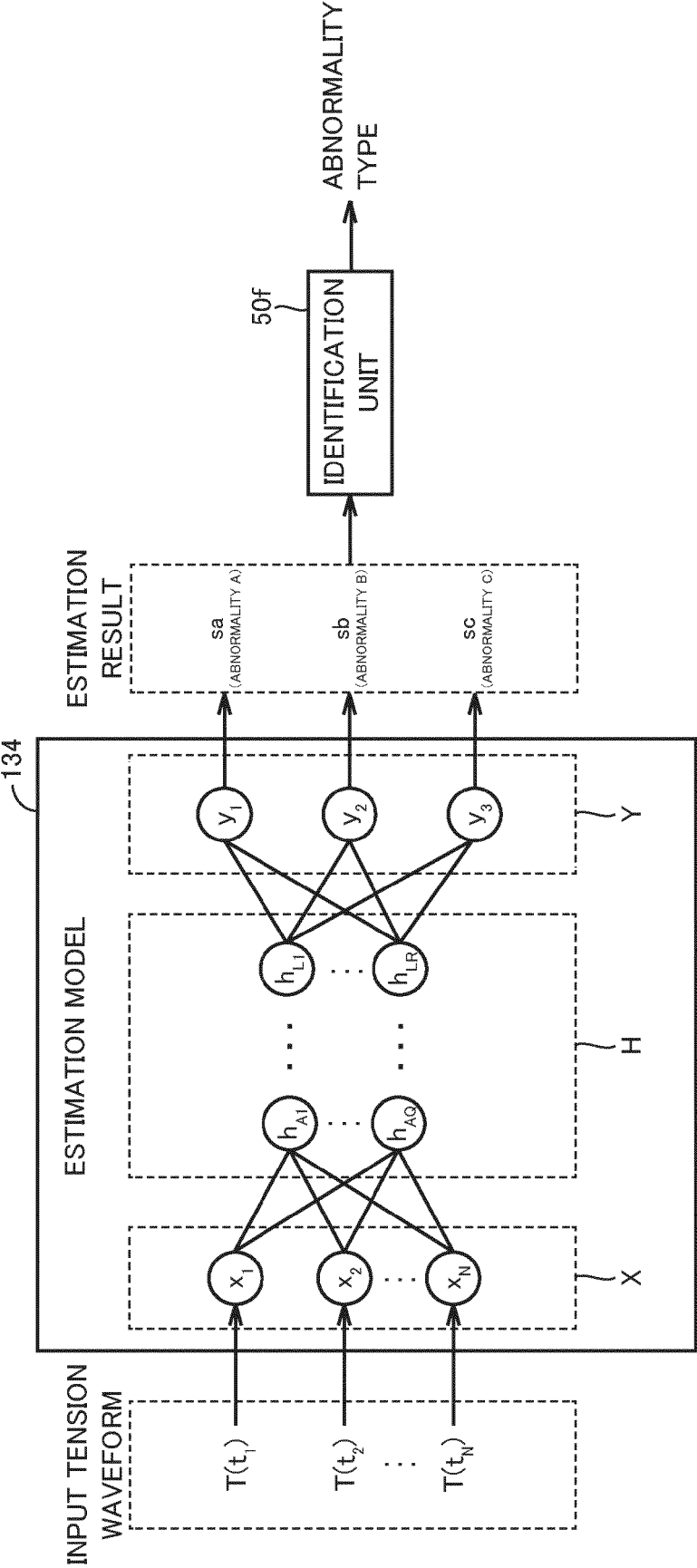


FIG.18





EUROPEAN SEARCH REPORT

Application Number

EP 23 20 9688

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EPO FORM 1503 03.82 (P04C01)

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X	JP 2004 183140 A (MURATA MACHINERY LTD; MASUDA ARATA) 2 July 2004 (2004-07-02) * page 2, line 36 - page 3, line 30 * * page 6, line 12 - page 9, line 32 * * page 10, line 32 - page 11, line 2 * -----	1-9	INV. B65H63/02 B65H63/04 D01H13/16 D01H13/20
A	EP 1 284 230 A1 (TEIJIN LTD [JP]) 19 February 2003 (2003-02-19) * paragraph [0016] - paragraph [0017] * * paragraph [0021] - paragraph [0022] * * paragraph [0030] - paragraph [0032] * -----	1-9	
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			B65H D01H
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 April 2024	Examiner Guisan, Thierry
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The members are as contained in the European Patent Office EDP file on
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26-04-2024

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