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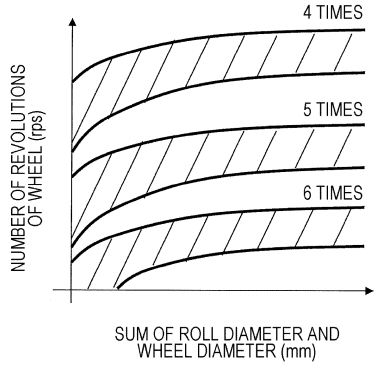
(54) ROLL GRINDER ABNORMAL VIBRATION PREDICTING METHOD, ROLLING ROLL GRINDING METHOD, METAL STRIP ROLLING METHOD, ROLL GRINDER ABNORMAL VIBRATION PREDICTING DEVICE, AND ROLL GRINDING EQUIPMENT

(57) An abnormal-vibration-predicting method for a roll grinder and an abnormal-vibration-predicting device for a roll grinder capable of predicting the abnormal vibration of the roll grinder corresponding to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece are provided.

An abnormal-vibration-predicting method for a roll grinder 10 that grinds an outer peripheral surface of a rolling roll 12 with a grinding wheel 14 while the rolling roll 12 rotates includes an acquisition step of acquiring a rigidity parameter related to a rigidity of the roll grinder 10 and a wheel rotation parameter related to a rotational speed of the grinding wheel 14, and a prediction step of predicting an occurrence of an abnormal vibration in a process of grinding the rolling roll 12 by using the rigidity parameter and the wheel rotation parameter.

FIG. 7



Description

Technical Field

[0001] The present invention relates to an abnormal-vibration-predicting method for a roll grinder, a rolling-roll-grinding method, a metal-strip-rolling method, an abnormal-vibration-predicting device for a roll grinder, and a roll-grinding apparatus.

Background Art

[0002] Chatter marks are examples of surface defects that occur in a cold rolling process. The chatter marks are surface defects including linear patterns that extend in a width direction of a metal strip caused by variations in the thickness of the metal strip and that appear periodically in a longitudinal direction of the metal strip. The chatter marks are known to occur due to rolling mill vibration (hereinafter referred to as chattering). The chatter marks formed on the metal strip by chattering lead to product defects due to poor appearance. If severe chattering occurs, the metal strip may break, for example, due to a sudden change in tension, and the productivity may be significantly reduced.

[0003] Chattering is often caused by, for example, flaws in rotating components, such as bearings, that constitute a rolling mill, poor lubrication between a rolling roll and the metal strip, or an abnormal profile of the rolling roll. In particular, when chattering occurs due to an abnormal profile of an outer peripheral surface of the rolling roll caused in a process of grinding the rolling roll, the vibration of the rolling mill continues until the rolling roll with the abnormal profile is replaced, and a large amount of product defects occur.

[0004] The abnormal profile of the rolling roll is caused by abnormal vibration of a grinder in the process of grinding the rolling roll as a workpiece. The vibration of the grinder generated in the process of grinding the rolling roll increases due to resonance when the natural frequency of a grinding wheel, the natural frequency of a workpiece support system, or the natural frequency of the entire mechanical system including the grinding wheel and the workpiece coincides with the excitation frequency. As a result, abnormal vibration of the roll grinder occurs.

[0005] As a technique for preventing the above-described abnormal vibration of the roll grinder, Patent Literature 1 discloses a method for preventing chatter vibration of a roll grinder. According to Patent Literature 1, the chatter vibration can be predicted based on the correlation between a chatter waveform detected by a chatter detector using an optical sensor and a vibration waveform measured by a vibration meter provided on a wheel spindle stock and a tail stock.

Citation List

Patent Literature

[0006] PTL 1: Japanese Unexamined Patent Application Publication No. 52-56468

Summary of Invention

Technical Problem

[0007] The method disclosed in Patent Literature 1 prevents the chatter vibration of the roll grinder. Since the chatter vibration occurs at a grinding point, which is the point of contact between the grinding wheel and the rolling roll serving as the workpiece, the method disclosed in Patent Literature 1 focuses on the vibration generated at the grinding point and transmitted to the roll grinder. However, the abnormal vibration generated in the roll grinder is caused not only by the vibration generated at the grinding point; the abnormal vibration may also occur due to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece. Therefore, the method disclosed in Patent Literature 1 has a problem in that it cannot predict the occurrence of the abnormal vibration corresponding to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece.

[0008] The present invention has been made to solve the above-described problem of the related art, and an object of the present invention is to provide an abnormal-vibration-predicting method for a roll grinder, an abnormal-vibration-predicting device for a roll grinder, and a roll-grinding apparatus capable of predicting the occurrence of the abnormal vibration of the roll grinder corresponding to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece. Another object of the present invention is to provide a rolling-roll-grinding method in which the occurrence of the abnormal vibration of the roll grinder is suppressed in a grinding process using the grinding wheel and a metal-strip-rolling method using the rolling roll ground by the rolling-roll-grinding method. Solution to Problem

[0009] Means for solving the above-described problem are as follows.

[1] An abnormal-vibration-predicting method for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting method including: an acquisition step of acquiring a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and a prediction step of predicting an occurrence of an abnormal vibration in a process of grinding the rolling roll by using the rigidity parameter and the wheel rotation parameter.

[2] The abnormal-vibration-predicting method for a roll grinder according to [1], wherein the rigidity parameter includes a distance between a rotation center of the rolling roll and a rotation center of the grinding wheel or a sum of a diameter of the rolling roll and a diameter of the grinding wheel.

[3] The abnormal-vibration-predicting method for a roll grinder according to [1], wherein, in the acquisition step, a load parameter related to a load applied to the grinding wheel is further acquired, and wherein, in the prediction step, the occurrence of the abnormal vibration in the process of grinding the rolling roll is predicted by using the rigidity parameter, the wheel rotation parameter, and the load parameter.

[4] The abnormal-vibration-predicting method for a roll grinder according to [3], wherein the load parameter includes a load current value of an electric motor that rotates the grinding wheel.

[5] an abnormal-vibration-predicting method for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting method including: an acquisition step of acquiring input data including a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and a prediction step of predicting an occurrence of an abnormal vibration in a process of grinding the rolling roll by using an abnormal-vibration-prediction model whose input is the input data and whose output is abnormal vibration information for the process of grinding the rolling roll.

[6] The abnormal-vibration-predicting method for a roll grinder according to [5], wherein the rigidity parameter includes a distance between a rotation center of the rolling roll and a rotation center of the grinding wheel or a sum of a diameter of the rolling roll and a diameter of the grinding wheel.

[7] The abnormal-vibration-predicting method for a roll grinder according to [5], wherein the input data acquired in the acquisition step includes the rigidity parameter, the wheel rotation parameter, and a load parameter related to a load applied to the grinding wheel.

[8] The abnormal-vibration-predicting method for a roll grinder according to [7], wherein the load parameter includes a load current value of an electric motor that rotates the grinding wheel.

[9] A rolling-roll-grinding method using the abnormal-vibration-predicting method for a roll grinder according to any one of [1] to [8], wherein, when the abnormal vibration is predicted to occur in the prediction step, grinding conditions of the roll grinder are changed to grinding conditions for which the abnormal vibration is not predicted to occur.

[10] A metal-strip-rolling method including rolling a metal strip in a rolling mill in which a rolling roll is installed, the rolling roll being ground by the rolling-roll-grinding method according to [9].

[11] An abnormal-vibration-predicting device for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting device including: a data acquisition unit that acquires input data including a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and an abnormal-vibration-prediction unit that predicts an occurrence of an abnormal vibration of the roll grinder by using an abnormal-vibration-prediction model whose input is the input data and whose output is abnormal vibration information.

[12] The abnormal-vibration-predicting device for a roll grinder according to [11], wherein the input data acquired by the data acquisition unit includes the rigidity parameter, the wheel rotation parameter, and a load parameter related to a load applied to the grinding wheel.

[13] The abnormal-vibration-predicting device for a roll grinder according to [11] or [12], further including: a guidance-information-acquisition unit that determines the input data for which the abnormal vibration does not occur by using the abnormal-vibration-prediction model.

[14] A roll-grinding apparatus including: a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates; and the abnormal-vibration-predicting device for a roll grinder according to [11] or [12].

[15] A roll-grinding apparatus including: roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates; and the abnormal-vibration-predicting device for a roll grinder according to [13].

Advantageous Effects of Invention

[0010] According to the present invention, the abnormal vibration of the roll grinder is predicted using the rigidity parameter and the wheel rotation parameter. Therefore, the occurrence of the abnormal vibration of the roll grinder corresponding to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece can be predicted.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a schematic diagram illustrating the structure of a roll-grinding apparatus capable of carrying out an abnormal-vibration-predicting method for a roll grinder according to a first embodiment.

[Fig. 2] Fig. 2 shows front views of roll grinders having grinding wheels with different diameters.

[Fig. 3] Fig. 3 is a graph showing the relationship between the sum of the diameter of the rolling roll and the diameter of the grinding wheel and the grinder rigidity.

[Fig. 4] Fig. 4 is a graph showing the relationship between the vibration frequency and the vibration intensity.

[Fig. 5] Fig. 5 is a graph showing the relationship between the wheel rotation frequency and the vibration intensity.

[Fig. 6] Fig. 6 is an abnormal vibration map related to the rigidity parameter.

[Fig. 7] Fig. 7 is an abnormal vibration map related to the rigidity parameter.

[Fig. 8] Fig. 8 is a graph showing the relationship between the wheel load current value and the grinder rigidity.

[Fig. 9] Fig. 9 is an abnormal vibration map related to the load parameter.

[Fig. 10] Fig. 10 is a schematic diagram illustrating a roll-grinding apparatus 110 capable of carrying out an abnormal-vibration-predicting method for a roll grinder according to a second embodiment.

[Fig. 11] Fig. 11 is a schematic diagram illustrating an example of the structure of an abnormal-vibration-predicting device 44.

[Fig. 12] Fig. 12 illustrates an example in which a neural network is used as an abnormal-vibration-prediction model.

[Fig. 13] Fig. 13 is a graph showing the measurement result of the vibration intensity.

[Fig. 14] Fig. 14 is a graph showing the measurement result of the vibration intensity.

Description of Embodiments

[First Embodiment]

[0012] A first embodiment of the present invention will now be described with reference to the drawings. Fig. 1 is a schematic diagram illustrating the structure of a roll-grinding apparatus 100 capable of carrying out an abnormal-vibration-predicting method for a roll grinder according to the first embodiment. Fig. 1(a) is a top view of the roll-grinding apparatus 100. Fig. 1(b) is a front view of a roll grinder 10. The roll grinder 10 illustrated in Fig. 1 is a roll grinder that uses a cylindrical grinding wheel to grind an outer peripheral surface of a rolling roll 12. The rolling roll 12 to be ground is carried to a roll shop by a crane or the like after being used in a rolling mill. After that, the rolling roll 12 is removed from a bearing box, allowed to be naturally cooled to normal temperature, and set to the roll grinder 10 individually.

[0013] The roll grinder 10 includes a grinding head 16 that supports a grinding wheel 14, a support table 18 that supports the grinding head 16, guides 26 and 28, a roll support base 68, and a vibration meter 32. The grinding head 16 supports the grinding wheel 14 and a wheel rotation motor 30 that drives the grinding wheel 14. A pulley and a belt for transmitting power are disposed between the grinding wheel 14 and the wheel rotation motor 30. The grinding wheel 14 may be rotationally driven directly by the wheel rotation motor 30.

[0014] The support table 18 is guided by the guide 26 and moves parallel to an axial direction of the rolling roll 12. The movement of the support table 18 along the guide 26 is performed under position control using a servo motor, so that the relative position between the grinding wheel 14 and the rolling roll 12 in the axial direction is controlled. The grinding head 16 is guided by the guide 28 and moves in a direction perpendicular to an axis of the rolling roll 12. The movement of the grinding head 16 along the guide 28 is also performed under position control using a servo motor, so that the cutting depth of the grinding wheel 14 is controlled. Alternatively, the support table 18 may be composed of a two-axis table that moves along the guide 26 and the guide 28. When the two-axis table is used, the support table 18 moves along the guide 26 disposed parallel to the axial direction of the rolling roll 12, and also moves the grinding wheel 14 along the guide 28 in a direction perpendicular to the axis of the rolling roll 12. In the following description, the structure composed of the grinding head 16, the support table 18, the guide 28, and the wheel rotation motor 30 that directly or indirectly support the grinding wheel 14 is referred to as a grinding-wheel support unit 66.

[0015] The roll support base 68 includes a roll chuck 20 that supports the rolling roll 12 at one end of the rolling roll 12 in the axial direction, a roll rotation motor 22 that rotationally drives the rolling roll 12 at a predetermined number of revolutions, and a tail stock 24 that supports the rolling roll 12 at the other end of the rolling roll 12 in the axial direction. The tail stock 24 serves to align the axis of the rolling roll 12 with an axis of a rotating shaft of the roll rotation motor 22. The tail stock 24 includes a cone-shaped portion that comes into contact with the rolling roll 12, and an end of the cone-shaped portion is inserted into a counterbore formed at the center of an axial end portion of the rolling roll 12 and a counterbore in a fixing jig. Thus, the rolling roll 12 is fixed with the axis thereof coinciding with the axis of the rotating shaft of the roll rotation motor 22. The number of revolutions of rolling roll 12 during grinding is controlled by a controller 42 of the roll grinder 10.

[0016] The rolling roll 12 is ground from one end to the other end in the axial direction of the rolling roll 12, and then continuously ground from the other end to the one end. The one-round trip of the grinding wheel 14 is defined as a traverse. A typical grinding process includes a rough grinding process in which the grinding amount is set to a large value, and a finish grinding process performed to finish the surface of the rolling roll 12. In general, the number of traverses for rough grinding is about 80 to 150, and the number of traverses for finish grinding is about 5 to 15. The rough grinding process is a grinding process performed to cut the surface of the rolling roll 12 to remove a fatigue layer and a portion having microscopic cracks. The finish grinding process is a weak grinding process performed to adjust the surface roughness of the rolling roll within a predetermined range.

[0017] The roll-grinding apparatus 100 illustrated in Fig. 1 further includes a control computer 40 and a controller 42. The control computer 40 sets grinding conditions for the rolling roll 12 to be ground based on information including the dimension information of the rolling roll 12, the grinding amount, and the target surface finish roughness.

[0018] The grinding conditions include at least three setting conditions: the number of revolutions of the roll, the number of revolutions of the grinding wheel 14, and the cutting depth of the grinding wheel 14 during grinding. The grinding conditions are set for each traverse from rough grinding to finish grinding. A current value set for the wheel rotation motor 30 may be used instead of the wheel cutting depth. An operator may check the state of grinding of the rolling roll 12 and adjust the grinding conditions of the roll grinder 10 as appropriate. In this case, the adjusted grinding conditions of the roll grinder 10 are output to the control computer 40.

[0019] The grinding conditions of the roll grinder 10 may be set by using a setting table that takes into account factors such as the diameter, surface hardness, and surface roughness before grinding of the rolling roll 12 to be ground. The grinding conditions are also set by taking into account the conditions of the grinding wheel 14, such as the grit number of the grinding wheel 14, the initial wheel diameter, the current wheel diameter, the cumulative grinding time of the grinding wheel 14, and the total grinding amount after dressing by a dressing device.

[0020] The initial wheel diameter is the wheel diameter before the first use of the grinding wheel 14 in roll grinding after production. The current wheel diameter is the wheel diameter measured before starting the grinding of the rolling roll 12 to be ground. Multiple locations are selected on the outer periphery of the grinding wheel 14, and the wheel diameter is measured using a micrometer at the selected locations. Alternatively, marks may be formed on a side surface of the grinding wheel 14 with a pitch of 1 to 5 mm in the radial direction in advance, and the wheel diameter may be determined by reading the marks. The grinding wheel 14 has an initial wheel diameter of 850 to 950 mm. The grinding wheel 14 is discarded when the wheel diameter is reduced to about 450 to 600 mm.

[0021] The control computer 40 sets control target values for operation conditions of the roll grinder 10. The controller 42 controls each device so that the number of revolutions of the roll, the number of revolutions of the grinding wheel 14, and the cutting depth of the grinding wheel 14 during grinding are equal to the control target values thereof in each traverse from the start to the end of the grinding operation. The controller 42 acquires an actual value of the wheel rotation motor 30 that drives the grinding wheel 14 during grinding. When actual values of the number of revolutions of the roll, the number of revolutions of the grinding wheel 14, and the cutting depth of the grinding wheel 14 during grinding can be measured, the controller 42 acquires these actual values. The thus-acquired actual values are output to the control computer 40 as data for analyzing the operational state of roll grinding. The control computer 40 and the controller 42 are workstations or general-purpose computers, such as personal computers. The control computer 40 and the controller 42 may be composed of a single computer.

[0022] In the above-described roll-grinding apparatus 100, the rolling roll 12 that has undergone finish grinding is transferred to a ground-roll storage area, and is returned to a roll replacing device and assembled into the rolling mill in its turn. The roll grinder 10 includes the vibration meter 32. The vibration meter 32 acquires actual data regarding abnormal vibration in the process of grinding the rolling roll. The vibration meter 32 is preferably installed on the grinding head 16 or the roll support base 68, and more preferably at a position close to the grinding wheel 14. When the vibration meter 32 is provided at such a position, vibration generated in at a contact portion between the grinding wheel 14 and the rolling roll 12 can be detected. Although the measurement direction of the vibration is not limited, the vibration in the same direction as the direction in which the grinding wheel 14 cuts into the rolling roll 12 is preferably measured.

[0023] In the abnormal-vibration-predicting method for a roll grinder according to the first embodiment, the abnormal vibration of the roll grinder 10 is predicted using a rigidity parameter related to the rigidity of the roll grinder 10 and a wheel rotation parameter related to the rotational speed of the grinding wheel 14. The rigidity parameter of the roll grinder 10 will now be described.

[0024] The rigidity parameter related to the rigidity of the roll grinder 10 means the parameter that influences the rigidity of the roll grinder 10 when the rolling roll 12 serving as the workpiece is supported by the roll support base 68. The rigidity of the roll grinder 10 represents the degree of influence of the external force applied to the roll grinder 10 on the displacement of a portion of the grinding wheel 14 in contact with the rolling roll 12.

[0025] Specifically, the rigidity of the grinding-wheel support unit 66 that directly or indirectly supports the grinding wheel 14 (hereinafter referred to as grinder rigidity) is defined as the rigidity parameter related to the rigidity of the roll grinder 10. The mass and the rigidity of the rolling roll 12 serving as the workpiece and the roll support base 68 are greater than the mass and the rigidity of the grinding-wheel support unit 66. Therefore, the contribution of the rolling roll 12 and the roll support base 68 on the overall vibration of the roll grinder 10 is small relative to that of the grinder rigidity. Therefore, it is not necessary that the rigidity parameter of the grinder 10 include the parameters of the rolling roll 12 serving as the workpiece and the roll support base 68.

[0026] The distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14 is preferably used as the rigidity parameter. This is because the position of the grinding head 16 relative to the support table 18 in the grinding process changes depending on the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14, and the ease of vibration of the grinding head 16 changes accordingly. The sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 may be used instead of the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14. In an example described below, the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 is used as the rigidity parameter.

[0027] Fig. 2 shows front views of roll grinders including grinding wheels having different diameters. Fig. 2(a) illustrates a roll grinder 70 having a large-diameter grinding wheel. Fig. 2(b) illustrates a roll grinder 80 having a small-diameter grinding wheel. When the diameter of the grinding wheel is small and the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel is short, the grinding head 16 needs to be moved forward toward the rolling roll 12 along the guide 28 to bring the grinding wheel 14 into contact with the rolling roll 12. Therefore, the distance between the rotation center of the grinding wheel 14 and the center of gravity of the grinding-wheel support unit 66 (hereinafter referred to as an arm length) is longer in the roll grinder 80 than in the roll grinder 70.

[0028] As the arm length increases, the rotational moment about the center of gravity of the grinding-wheel support unit 66 increases even when the grinding force applied between the rolling roll 12 and the grinding wheel 14 (tangential force in the direction of rotation of the grinding wheel) is constant. Therefore, the rigidity of the grinding-wheel support unit 66 changes, and the vibration of the roll grinder changes accordingly. In other words, when the distance between the rotation center of the rolling roll and the rotation center of the grinding wheel 14 is short and the above-described arm length is long, the rigidity of the roll grinder is reduced.

[0029] Fig. 3 is a graph showing the relationship between the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 and the grinder rigidity. In Fig. 3, the horizontal axis represents the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 (mm), and the vertical axis represents the grinder rigidity (N/mm). The grinder rigidity is determined by approximating the grinding-wheel support unit 66 with a vibration model of a mass-spring-damper system and determining the parameters of the vibration model to match the relationship between the vibration frequency and the vibration intensity measured by the vibration meter. Alternatively, a hammering test may be performed on the grinding-wheel support unit 66 to measure the natural frequency, and the grinder rigidity may be calculated from the mass of the grinding-wheel support unit 66.

[0030] As illustrated in Fig. 3, the grinder rigidity increases as the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 increases, that is, as the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14 increases. This result shows that when the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14 increases, the ease of vibration of the grinding-wheel support unit 66 changes, and the grinder rigidity tends to increase accordingly. This is because when the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 increases, the arm length decreases and the rotational moment around the center of gravity of the grinding-wheel support unit 66 decreases accordingly. It is clear from this result that the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 is preferably used as the rigidity parameter.

[0031] The wheel rotation parameter related to the rotational speed of the grinding wheel 14 will now be described. The wheel rotation parameter is the parameter related to the rotational speed of the grinding wheel 14 among the parameters representing the grinding conditions under which the rolling roll 12 is ground. Specifically, one of the number of revolutions, the rotation frequency, and the rotational angular speed of the grinding wheel 14 may be used as the wheel rotation parameter, and the number of revolutions, the rotation frequency, and the rotational angular speed of the wheel rotation motor 30 that drives the grinding wheel 14 may be used as these values. The wheel rotation parameter affects the vibration of the grinding-wheel support unit 66 as the frequency of the vibration source that externally acts on the grinding-wheel support unit 66. In other words, the vibration of the roll grinder 10 is determined by the rigidity of the grinding-wheel support unit 66 that supports the grinding wheel 14 and the frequency of the vibration source.

[0032] Fig. 4 is a graph showing the relationship between the vibration frequency and the vibration intensity. Fig. 4 shows the frequency spectrum for a specific number of revolutions of the wheel. In Fig. 4, the horizontal axis represents the vibration frequency (Hz) and the vertical axis represents the vibration intensity (m/sec^2). The graph of Fig. 4 shows the vibration intensity measured when the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 and the wheel load current value, which is a load parameter, are constant and when the number of revolutions of the wheel is 8.5 rps (frequency corresponding to the wheel rotation is 8.5 Hz).

[0033] As illustrated in Fig. 4, the vibration intensity of the roll grinder 10 measured by the vibration meter 32 has peaks at vibration frequencies corresponding to integer multiples of the number of revolutions of the wheel. However, the vibration at the wheel rotation frequency of 60 Hz is a disturbance caused by the frequency of the power supply system and not the vibration intensity of the roll grinder 10. Thus, it is clear that the vibration intensity has peaks at integer multiples of a specific number of revolutions of the wheel. In the first embodiment, the peak values at the frequencies equal to the integer multiples of a specific number of revolutions N of the wheel is defined as PNi. Here, i is the multiple for the number of revolutions of the wheel, and i is any integer of 1 or more. The multiple i for the number of revolutions of the wheel may be determined in the range of 6 to 12 at a maximum. This is because the occurrence of the abnormal vibration may not be predictable when the maximum value of the multiple i for the number of revolutions of the wheel is less than 6, and the peak values of the vibration tend to be smaller when the maximum value of the multiple i for the number of revolutions of the wheel is greater than 12.

[0034] Fig. 5 is a graph showing the relationship between the wheel rotation frequency and the vibration intensity. In Fig. 5, the horizontal axis represents the wheel rotation frequency (Hz) and the vertical axis represents the vibration intensity (m/sec^2). The graph shown in Fig. 5 is obtained by changing the number of revolutions N of the wheel while the rigidity parameter is maintained constant, determining the peak values PNi (i = 1 to 6) corresponding to the frequencies of integer multiples of the number of revolutions of the wheel, and plotting the determined values for each multiple i. The graph shown in Fig. 5 plots the peak intensities for each multiple i for the number of revolutions of the wheel. This graph is referred to as a peak intensity map.

[0035] As illustrated in Fig. 5, when the number of revolutions N of the wheel is changed while the rigidity parameter is constant, the vibration intensity has peaks corresponding to the frequencies of integer multiples of the number of revolutions N of the wheel. In other words, if the relationship illustrated in Fig. 5 is known, it becomes clear how the peak value of the vibration intensity changes for each of the integer multiples i of the number of revolutions N of the wheel when the number of revolutions N of the wheel, which is the wheel rotation parameter, is changed. Thus, when the relationship between the wheel rotation frequency and the vibration intensity is determined, the range of the number of revolutions N of the wheel in which the abnormal vibration of the roll grinder 10 occurs and the multiple i corresponding thereto can be determined by setting the threshold for the abnormal vibration (for example, 10^{-1} m/s^2).

[0036] When the relationship illustrated in Fig. 5 is obtained while changing the rigidity parameter, an abnormal vibration map for the roll grinder 10 can be created. Fig. 6 is an abnormal vibration map related to the rigidity parameter. In Fig. 6, the horizontal axis represents the sum (mm) of the wheel diameter and the rolling roll diameter, and the vertical axis represents the number of revolutions of the wheel (rps).

[0037] In the abnormal vibration map illustrated in Fig. 6, the sums (4 points) of the diameter of the rolling roll and the diameter of the grinding wheel are set on the horizontal axis as the rigidity parameter, and bars representing the ranges of the number of revolutions N of the wheel in which the vibration intensity exceeds the threshold are shown for each multiple i. The abnormal vibration map shown for discrete values of the parameter represented by the horizontal axis as in Fig. 6 is referred to as a discrete abnormal vibration map. The discrete abnormal vibration map is preferably created by changing the condition of the rigidity parameter to 3 or more and 15 or less values. When the discrete abnormal vibration map is created by changing the condition of the rigidity parameter to less than 3 values, the abnormal vibration that occurs under the condition of a different value of the rigidity parameter cannot be easily predicted. When the discrete abnormal vibration map is created by changing the condition of the rigidity parameter to more than 15 values, the workload of creating the map increases with no significant improvement in the prediction accuracy of the abnormal vibration.

[0038] It is clear from Fig. 6 that the ranges in which the abnormal vibration of the roll grinder 10 occurs are determined by the number of revolutions of the wheel, which is the wheel rotation parameter related to the rotational speed of the grinding wheel 14. It is also clear that the ranges of the number of revolutions of the wheel in which the abnormal vibration occurs vary depending on the sum of the diameter of the rolling roll and the diameter of the grinding wheel, which is the rigidity parameter.

[0039] Referring to Fig. 6, when the sum of the diameter of the rolling roll and the diameter of the grinding wheel is constant, the vibration intensity of the roll grinder 10 exceeds the threshold in the ranges of the number of revolutions of the wheel shown by the bars in Fig. 6. Therefore, it can be predicted that, in these ranges, the abnormal vibration of the roll grinder 10 will occur in the process of grinding the rolling roll. Fig. 6 is an example in which the threshold of the abnormal vibration is set to 10^{-1} m/s^2. The threshold of the vibration intensity may be determined based on actual values of the vibration data obtained during roll grinding of the rolling roll in which chattering has occurred.

[0040] Fig. 7 is another example of an abnormal vibration map related to the rigidity parameter. The vibration map illustrated in Fig. 7 is obtained by connecting, with continuous curves, the upper limits and the lower limits of the ranges of the number of revolutions of the wheel in which the abnormal vibration occurs for the same multiple in the abnormal vibration map illustrated in Fig. 6. By creating this abnormal vibration map, the range in which the abnormal vibration of the roll grinder 10 occurs can be determined for each multiple i for the number of revolutions of the wheel for any sum of the diameter of the rolling roll and the diameter of the grinding wheel. Thus, the abnormal vibration of the rolling roll can be predicted. An abnormal vibration map shown for continuous changes in the parameter represented by the horizontal axis as in Fig. 7 is referred to as a continuous abnormal vibration map.

[0041] When the continuous abnormal vibration map illustrated in Fig. 7 is prepared in advance, the occurrence of the abnormal vibration in the process of grinding the rolling roll 12 using the roll grinder 10 can be predicted by acquiring the sum of the diameter of the rolling roll and the diameter of the grinding wheel as the rigidity parameter and the number of revolutions of the grinding wheel 14 as the wheel rotation parameter.

[0042] In the abnormal-vibration-predicting method for a roll grinder according to the first embodiment, an acquisition step is executed to acquire the rigidity parameter and the wheel rotation parameter. After that, a prediction step is executed to predict the abnormal vibration in the process of grinding the rolling roll by using the parameters and the abnormal vibration map (continuous abnormal vibration map) illustrated in Fig. 7 prepared in advance. Thus, the abnormal vibration of the roll grinder 10 corresponding to the natural frequency of the entire mechanical system including the grinding wheel 14 and the workpiece can be predicted.

[0043] The load parameter related to the load applied to the grinding wheel 14 will now be described. In the abnormal-vibration-predicting method for a roll grinder according to the first embodiment, the load parameter may be additionally used, and the abnormal vibration of the roll grinder 10 may be predicted using the rigidity parameter, the wheel rotation parameter, and the load parameter.

[0044] The load parameter related to the load applied to the grinding wheel 14 is the parameter related to the load (load, tangential force) applied to the contact portion between the grinding wheel 14 and the rolling roll 12 in the grinding process. The load parameter may be a load current value of the wheel rotation motor 30, which is an electric motor that rotates the grinding wheel 14 (hereinafter referred to as a wheel load current value) or the wheel cutting depth in the grinding process.

[0045] The load parameter related to the load applied to the grinding wheel 14 affects the elastic deformation of the contact portion between the grinding wheel 14 and the rolling roll 12. The load parameter also affects the mechanical rattling of the grinding-wheel support unit 66, and therefore indirectly affects the grinder rigidity. When the load parameter, which is the wheel cutting depth or the wheel load current value, is large, the reaction force that the grinding wheel 14 receives from the rolling roll 12 increases, and the force received by the grinding-wheel support unit 66 also increases. As a result, the mechanical rattling of the grinding-wheel support unit 66 is suppressed, and the apparent rigidity of the grinding-wheel support unit 66 increases.

[0046] Fig. 8 is a graph showing the relationship between the wheel load current value and the grinder rigidity. In Fig. 8, the horizontal axis represents the wheel load current value (A), and the vertical axis represents the grinder rigidity (N/mm). The graph shown in Fig. 8 is the result obtained by studying the relationship between the wheel load current value and the grinder rigidity when the sum of the diameter of the rolling roll and the diameter of the grinding wheel is constant in the rough grinding process performed by the roll grinder 10. It is clear from Fig. 8 that when the wheel load current value increases, the apparent rigidity of the grinding-wheel support unit 66 varies, and the rigidity of the roll grinder 10 tends to increase.

[0047] Fig. 9 shows the abnormal vibration map (continuous abnormal vibration map) related to the load parameter. In Fig. 9, the horizontal axis represents the wheel load current value (A), and the vertical axis represents the number of revolutions of the wheel (rps). The abnormal vibration map illustrated in Fig. 9 can be created by the same method as that for creating the abnormal vibration map for the rigidity parameter described in Figs. 4 to 7. Specifically, the frequency spectrum for a specific number of revolutions of the wheel is measured, and a peak intensity map is created by plotting the peak intensities for each multiple i for the number of revolutions of the wheel. Then, multiple peak intensity maps are created by changing the load parameter, and the continuous abnormal vibration map related to the load parameter is created from a discrete abnormal vibration map related to the load parameter.

[0048] As illustrated in Figs. 8 and 9, the load parameter affects the rigidity of the roll grinder 10, and therefore affects the occurrence of the abnormal vibration of the roll grinder 10. Accordingly, it is clear that the load parameter is preferably additionally used, and that the abnormal vibration of the roll grinder 10 is preferably predicted using the rigidity parameter, the wheel rotation parameter, and the load parameter. In particular, the abnormal vibration of the roll grinder 10 is preferably predicted by using the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14 or the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14 as the rigidity parameter, the wheel load current value as the load parameter, and the wheel rotation parameter in addition to the above-described parameters. This is because the prediction accuracy of the abnormal vibration of the roll grinder 10 increases by using the structural rigidity and the apparent rigidity of the grinding-wheel support unit 66. Specifically, the abnormal vibration map (continuous abnormal vibration map) related to the rigidity parameter illustrated in Fig. 7 may be prepared for each load parameter, and the abnormal vibration of the roll grinder 10 may be predicted using the abnormal vibration map related to the rigidity parameter corresponding to the acquired load parameter. Thus, the prediction accuracy of the occurrence of the abnormal vibration of the roll grinder 10 can be increased.

[Second Embodiment]

[0049] A second embodiment of the present invention will now be described. Fig. 10 is a schematic diagram illustrating a roll-grinding apparatus 110 capable of carrying out an abnormal-vibration-predicting method for a roll grinder according to the second embodiment. The roll-grinding apparatus 110 differs from the roll-grinding apparatus 100 illustrated in Fig. 1 in that an abnormal-vibration-predicting device 44 is additionally provided. Elements of the roll-grinding apparatus 110 that are the same as those of the roll-grinding apparatus 100 illustrated in Fig. 1 are denoted by the same reference numerals, and redundant descriptions thereof will be omitted.

[0050] In the abnormal-vibration-predicting method for a roll grinder according to the second embodiment, the abnormal vibration in the process of grinding the rolling roll is predicted by using an abnormal-vibration-prediction model whose input is input data including the rigidity parameter related to the rigidity of the roll grinder and the wheel rotation parameter related to the rotational speed of the grinding wheel 14, and whose output is abnormal vibration information for the process of grinding the rolling roll.

[0051] Fig. 11 is a schematic diagram illustrating an example of the structure of the abnormal-vibration-predicting device 44. The abnormal-vibration-predicting device 44 is, for example, a workstation or a general-purpose computer, such as a personal computer. The abnormal-vibration-predicting device 44 includes a control unit 46, an input unit 48, an output unit 50, and a storage unit 52. The control unit 46 is, for example, a CPU and executes programs read from the storage unit 52 so that the control unit 46 functions as a data acquisition unit 54, an abnormal-vibration-prediction unit 56, a prediction-model-generating unit 58, and a guidance-information-acquisition unit 60.

[0052] The input unit 48 is, for example, a keyboard or a touch panel provided integrally with a display. The output unit 50 is, for example, an LCD or a CRT display. The storage unit 52 is, for example, an information recording medium, such as a re-recordable flash memory, a hard disk that is built-in or connected with a data communication terminal, or a memory card, and a read/write device for the information recording medium. The storage unit 52 stores a database 62, an abnormal-vibration-prediction model 64, programs for causing the control unit 46 to execute functions, and data used by the programs.

[0053] The processes performed by the data acquisition unit 54, the abnormal-vibration-prediction unit 56, the guidance-information-acquisition unit 60, and the prediction-model-generating unit 58 will now be described. The data acquisition unit 54 acquires the rigidity parameter related to the rigidity of the roll grinder 10 and the wheel rotation parameter related to the rotational speed of the grinding wheel 14 as input data.

[0054] The data acquisition unit 54 executes an acquisition step to acquire the rigidity parameter and the wheel rotation parameter. The rigidity parameter acquired by the data acquisition unit 54 may be an operation parameter related to the rigidity of the grinding-wheel support unit 66. The operation parameter related to the rigidity of the grinding-wheel support unit 66 may be, for example, at least one of the distance between the rotation center of the rolling roll 12 and the rotation center of the grinding wheel 14 and the sum of the diameter of the rolling roll 12 and the diameter of the grinding wheel 14. The wheel rotation parameter acquired by the data acquisition unit 54 may be an operation parameter related to the rotational speed of the grinding wheel 14. The operation parameter related to the rotational speed of the grinding wheel 14 may be, for example, at least one of the number of revolutions, the rotation frequency, and the rotational angular speed of the grinding wheel 14. The values of the number of revolutions, the rotation frequency, and the rotational angular speed of the wheel rotation motor 30 that drives the grinding wheel 14 may be used as the above-described values. These parameters affect the occurrence of the abnormal vibration of the roll grinder 10 corresponding to the natural frequency of the entire mechanical system including the grinding wheel and the workpiece. Therefore, when these data are included in the input data, the abnormal-vibration-prediction model 64 serves as an abnormal-vibration-prediction model that outputs the abnormal vibration information corresponding to the natural frequency.

[0055] The data acquisition unit 54 may acquire the input data from the control computer 40 or by an input operation performed on the input unit 48 by the operator. The data acquisition unit 54 outputs the input data to the abnormal-vibration-prediction unit 56.

[0056] Preferably, the data acquisition unit 54 executes the acquisition step to further acquire the load parameter related to the load applied to the grinding wheel 14 as the input data. The load parameter acquired by the data acquisition unit 54 may be an operation parameter related to the load applied to the contact portion between the grinding wheel 14 and the rolling roll 12, and may be, for example, at least one of the wheel load current value and the wheel cutting depth in the grinding process. As described above, the load parameter affects the occurrence of the abnormal vibration. Therefore, when the input data includes the rigidity parameter, the wheel rotation parameter, and the load parameter, the prediction accuracy of the occurrence of the abnormal vibration can be increased.

[0057] The data acquisition unit 54 acquires datasets, each of which is composed of actual data of the rigidity parameter, actual data of the wheel rotation parameter, and actual data of the abnormal vibration information, and stores the datasets in the database 62 of the storage unit 52. The data acquisition unit 54 may either acquire the datasets of the actual data stored in the control computer 40, or acquire the datasets of the actual data by an input operation performed on the input unit 48 by the operator. The data acquisition unit 54 may acquire the actual data individually. In this case, the individual actual data may be stored temporarily until the corresponding other actual data are acquired to complete a dataset, and then stored in the database 62.

[0058] The database 62 preferably stores 100 or more datasets. More preferably, the database 62 stores 200 or more datasets. Still more preferably, the database 62 stores 500 or more datasets. The data acquisition unit 54 may perform screening on the datasets stored in the database 62 under predetermined conditions. An upper limit may be set for the number of datasets stored in the database 62. When the upper limit is reached, the data acquisition unit 54 may store additional datasets by deleting the oldest datasets and updating the datasets stored in the database 62.

[0059] When the abnormal-vibration-prediction unit 56 acquires the input data from the data acquisition unit 54, the abnormal-vibration-prediction unit 56 executes a prediction step to predict the abnormal vibration in the process of grinding the rolling roll 12 by using the abnormal-vibration-prediction model. The abnormal-vibration-prediction model is, for example, a pre-trained machine learning model that outputs the abnormal vibration information for the process of grinding the rolling roll 12 when the input data including the rigidity parameter and the wheel rotation parameter is input. The abnormal vibration information is information regarding the abnormal vibration in the process of grinding the rolling roll 12. The abnormal vibration information may be, for example, information showing the presence or absence of the occurrence of the abnormal vibration in the grinding process or information showing the vibration intensity of the vibration that occurs in the grinding process. When the abnormal vibration information is the information showing the vibration intensity, the storage unit 52 stores the threshold for the vibration intensity corresponding to the abnormal vibration in advance. The abnormal-vibration-prediction unit 56 reads the threshold from the storage unit 52 and compares the threshold with the output information showing the vibration intensity to predict the occurrence of the abnormal vibration in the process of grinding the rolling roll 12.

[0060] Neural networks (including deep learning and convolutional neural networks), decision tree learning, random forests, support vector regression, etc., may be used as the machine learning model. Also, an ensemble model in which multiple models are combined and a classification model, such as the k-nearest neighbor method or logistic regression, may also be used.

[0061] Fig. 12 illustrates an example in which a neural network is used as the abnormal-vibration-prediction model. In Fig. 12, L1 denotes an input layer, L2 an intermediate layer, and L3 an output layer. When this type of machine learning model is used, any parameters having correlations with the abnormal vibration of the roll grinder 10 can be selected as inputs without considering the problem of multicollinearity. Therefore, the prediction accuracy of the abnormal vibration of the roll grinder 10 can be increased. For example, a neural network having two intermediate layers and three nodes can be used, and a sigmoid function may be used as the activation function.

[0062] The prediction-model-generating unit 58 generates a pre-trained machine learning model by training a machine learning model using the datasets stored in the database 62. The prediction-model-generating unit 58 stores the generated pre-trained machine learning model in the storage unit 52 as the abnormal-vibration-prediction model. The prediction-model-generating unit 58 may perform training by dividing the datasets stored in the database 62 into training data and test data to improve the estimation accuracy of the abnormal vibration. For example, the prediction-model-generating unit 58 may use the training data for machine learning on the weighting coefficients of the neural network, and use the test data to change the structure of the neural network as appropriate to increase the accuracy rate of the prediction of the abnormal vibration of the roll grinder 10. The structure of the neural network to be changed is, for example, the numbers of intermediate layers and nodes. Thus, the prediction accuracy of the abnormal vibration of the roll grinder 10 can be increased.

[0063] The prediction-model-generating unit 58 may update the weighting coefficients of the pre-trained machine learning model using the back propagation method. The prediction-model-generating unit 58 may update the generated pre-trained machine learning model every six months using the datasets stored in the database 62. As the number of datasets used for machine learning increases, the abnormal vibration of the roll grinder 10 can be predicted with higher accuracy. By using new datasets for machine learning, the abnormal-vibration-prediction model reflecting the recent state of the roll grinder 10 can be generated, and the abnormal vibration of the roll grinder 10 can be predicted with higher accuracy.

[0064] The abnormal-vibration-prediction unit 56 predicts the occurrence of the abnormal vibration in the process of grinding the rolling roll 12 by inputting the input data including the rigidity parameter and the wheel rotation parameter to the abnormal-vibration-prediction model and causing the abnormal-vibration-prediction model to output the abnormal vibration information. When the abnormal-vibration-prediction unit 56 predicts the occurrence of the abnormal vibration in the process of grinding the rolling roll 12, the abnormal-vibration-prediction unit 56 causes the output unit 50 to display the prediction result. The operator can check whether or not the abnormal vibration occurs in the process of grinding the rolling roll 12 by visually checking the display.

[0065] When the abnormal vibration of the roll grinder 10 is predicted to occur or when an instruction to execute a guidance information acquisition step is input by an input operation performed on the input unit 48 by the operator, the guidance-information-acquisition unit 60 executes the guidance information acquisition step. The guidance-information-acquisition unit 60 uses the abnormal-vibration-prediction model to determine the input data for which the abnormal vibration of the roll grinder 10 does not occur. When the abnormal vibration of the roll grinder 10 is predicted to occur, the guidance-information-acquisition unit 60 reads a table showing the combinations of the input data from the storage unit 52. The guidance-information-acquisition unit 60 inputs the input data to the abnormal-vibration-prediction model with reference to the table and causes the abnormal-vibration-prediction model to output the abnormal vibration information.

[0066] The guidance-information-acquisition unit 60 determines the combinations of the input data for which the output abnormal vibration information indicates that the abnormal vibration does not occur. The guidance-information-acquisition unit 60 causes the output unit 50 to display the determined combinations of the input data. The operator can check the rigidity parameter and the wheel rotation parameter for which the abnormal vibration does not occur in the roll grinding process by visually checking the display.

[0067] Thus, in the abnormal-vibration-predicting method for a roll grinder according to the second embodiment, first, the acquisition step is executed. In this step, the data acquisition unit 54 acquires the input data including the rigidity parameter and the wheel rotation parameter. After that, the prediction step is executed. In this step, the abnormal-vibration-prediction unit 56 inputs the input data including the rigidity parameter and the wheel rotation parameter to the abnormal-vibration-prediction model and causes the abnormal-vibration-prediction model to output the abnormal vibration information for the process of grinding the rolling roll 12. Thus, the occurrence of the abnormal vibration information in the process of grinding the rolling roll 12 can be predicted.

[0068] In the example illustrated in Fig. 11, the abnormal-vibration-predicting device 44 includes the prediction-model-generating unit 58. However, it is not necessary that the abnormal-vibration-predicting device 44 include the prediction-model-generating unit 58. When the abnormal-vibration-predicting device 44 does not include the prediction-model-generating unit 58, the abnormal-vibration-prediction model can be provided from the outside through the input unit 48 and stored in the storage unit 52. In addition, although the abnormal-vibration-predicting device 44 includes the guidance-information-acquisition unit 60 in the above-described example, it is not necessary that the abnormal-vibration-predicting device 44 include the guidance-information-acquisition unit 60. However, when the guidance-information-acquisition unit 60 is included, the rigidity parameter and the wheel rotation parameter for which the abnormal vibration does not occur can be determined, and the grinding conditions for which the abnormal vibration does not occur can be set based on these parameters. Therefore, the abnormal-vibration-predicting device 44 preferably includes the guidance-information-acquisition unit 60.

[0069] In addition, in the abnormal-vibration-predicting method for a roll grinder according to the second embodiment, the pre-trained machine learning model is used as the abnormal-vibration-prediction model. However, a multiple regression model may also be used as the abnormal-vibration-prediction model. In this case, the input of the machine learning model serves as an explanatory variable, and the output of the machine learning model serves as a target variable. Also when the multiple regression model is used, the parameters for the multiple regression model are determined in advance by using the datasets stored in the database 62, and the determined parameters are stored in the storage unit 52. The abnormal-vibration-predicting device 44 and one of the control computer 40 and the controller 42 may be composed of a single computer. Alternatively, the control computer 40, the controller 42, and the abnormal-vibration-predicting device 44 may be composed of a single computer.

[0070] It has been described above that the occurrence of the abnormal vibration in the process of grinding the rolling roll 12 can be predicted by using the abnormal-vibration-predicting method for a roll grinder according to the first embodiment of the present invention and the abnormal-vibration-predicting method for a roll grinder according to the second embodiment of the present invention. By using these abnormal-vibration-predicting methods for a roll grinder, a method for griding the rolling roll 12 while suppressing the occurrence of the abnormal vibration during roll grinding can be provided. According to this method for grinding the rolling roll 12, when the abnormal vibration of the roll grinder 10 is predicted to occur by the abnormal-vibration-predicting method for a roll grinder, the outer peripheral surface of the rolling roll 12 is ground after changing the grinding conditions of the roll grinder 10 to grinding conditions for which the abnormal vibration is not predicted to occur.

[0071] For example, assume that the abnormal vibration is predicted to occur in the process of grinding the rolling roll 12 by the abnormal-vibration-predicting method for a roll grinder according to the first embodiment. In such a case, the grinding conditions can be reset by referring to the abnormal vibration map related to the rigidity parameter illustrated in Fig. 7 so that the grinding conditions for the rolling roll 12 are not within the high-risk regions in the abnormal vibration map.

[0072] The prediction of the occurrence of the abnormal vibration by the abnormal-vibration-predicting method for a roll grinder according to the first embodiment may be performed before starting the process of grinding the rolling roll 12. In this case, the acquisition step is executed before the process of grinding the rolling roll 12 is started. The set value of the rigidity parameter and the set value of the wheel rotation parameter are acquired, and the set value of the load parameter is also acquired as necessary. Then, the prediction step is executed. Accordingly, the occurrence of the abnormal vibration of the roll grinder 10 can be predicted before the process of grinding the rolling roll 12 is started, and appropriate grinding conditions for which the abnormal vibration is not predicted to occur can be set.

[0073] The prediction of the occurrence of the abnormal vibration may be performed after starting the process of grinding the rolling roll 12. In this case, the acquisition step is executed after the process of grinding the rolling roll 12 is started. The actual value of the rigidity parameter and the actual value of the wheel rotation parameter are acquired, and the actual value of the load parameter is also acquired as necessary. Then, the prediction step is executed. Accordingly, the occurrence of the abnormal vibration of the roll grinder 10 can be predicted during the process of grinding the rolling roll 12 is started, and grinding conditions can be reset to appropriate grinding conditions for which the abnormal vibration is not predicted to occur.

[0074] The rolling roll 12 ground by the method for grinding the rolling roll 12 in which the grinding conditions are reset to appropriate grinding conditions is preferably installed in a rolling mill to roll a metal strip. Since the rolling roll 12 ground under the conditions for which the abnormal vibration of the roll grinder 10 does not occur is installed, rolling of the metal strip can be performed while suppressing the occurrence of chattering.

[0075] When the abnormal vibration is predicted to occur in the process of grinding the rolling roll 12 by the abnormal-vibration-predicting method for a roll grinder according to the second embodiment, the grinding conditions are changed, and the occurrence of the abnormal vibration is predicted again by the abnormal-vibration-predicting method for a roll grinder. This may be repeated, and the grinding conditions may be reset to those corresponding to the rigidity parameter and the wheel rotation parameter for which the abnormal vibration is not predicted to occur. When the guidance-information-acquisition unit 60 is provided, the grinding conditions may be reset to those corresponding to the rigidity parameter and the wheel rotation parameter determined by the guidance-information-acquisition unit 60 as parameters for which the abnormal vibration is not predicted to occur. When the grinding conditions of the rolling roll 12 are set as described above, the rolling roll 12 can be ground while suppressing the occurrence of the abnormal vibration corresponding to the natural frequency of the entire mechanical system including the grinding wheel 14 and the workpiece.

[0076] The prediction of the occurrence of the abnormal vibration by the abnormal-vibration-predicting method for a roll grinder according to the second embodiment may be performed before starting the process of grinding the rolling roll 12. In this case, the acquisition step is executed before the process of grinding the rolling roll 12 is started. The set value of the rigidity parameter and the set value of the wheel rotation parameter are acquired, and the set value of the load parameter is also acquired as necessary. Then, the prediction step is executed. Accordingly, the occurrence of the abnormal vibration of the roll grinder 10 can be predicted before the process of grinding the rolling roll 12 is started, and appropriate grinding conditions for which the abnormal vibration is not predicted to occur can be set.

[0077] The prediction of the occurrence of the abnormal vibration may be performed after starting the process of grinding the rolling roll 12. In this case, the acquisition step is executed after the process of grinding the rolling roll 12 is started. The actual value of the rigidity parameter and the actual value of the wheel rotation parameter are acquired, and the actual value of the load parameter is also acquired as necessary. Then, the prediction step is executed. Accordingly, the occurrence of the abnormal vibration of the roll grinder 10 can be predicted during the process of grinding the rolling roll 12 is started, and grinding conditions can be reset to appropriate grinding conditions for which the abnormal vibration is not predicted to occur.

[0078] The rolling roll 12 ground by the method for grinding the rolling roll 12 in which the grinding conditions are reset to appropriate grinding conditions is preferably installed in a rolling mill to roll a metal strip. Since the rolling roll 12 ground under the conditions for which the abnormal vibration of the roll grinder 10 does not occur is installed, rolling of the metal strip can be performed while suppressing the occurrence of chattering.

Examples

[Example 1]

[0079] Example 1 will now be described. In Example 1, a rolling roll for use in a cold tandem rolling mill was ground while predicting the occurrence of the abnormal vibration using the abnormal-vibration-predicting method for a roll grinder according to the first embodiment. In Example 1, a vibration meter mounted on the roll grinder was used to obtain vibration data of the roll grinder under various grinding conditions, and the abnormal vibration map (continuous abnormal vibration map) illustrated in Fig. 7 was created to determine the relationship between the ranges of the number of revolutions of the wheel in which the abnormal vibration of the rolling roll occurs and the rigidity parameter of the roll grinder. The threshold for the abnormal vibration was set to 10^{-1} m/s^2. The abnormal vibration map related to the rigidity parameter illustrated in Fig. 7 was created for each wheel load current value, which is the load parameter. The abnormal vibration maps related to the rigidity parameter were used to predict the occurrence of the abnormal vibration of the roll grinder. The grinding wheel used in roll grinding was a cylindrical alumina-based wheel. The current wheel diameter of the grinding wheel was 635 mm. The diameter of the rolling roll serving as a workpiece was 1370 mm.

[0080] Rough grinding was selected for the traverses in the roll grinding process, and the grinding conditions were set as follows: the load current value was 120 A, the number of revolutions of the wheel was 750 rpm, the number of revolutions of the rolling roll was 10 rpm, and the traverse rate was 2 mm/pass. However, according to the abnormal vibration map (continuous abnormal vibration map) related to the rigidity parameter created in advance, the vibration intensity was increased for three times the number of revolutions N of the wheel, and the abnormal vibration of the roll grinder was predicted to occur. Accordingly, the number of revolutions of the wheel was changed to 630 rpm to reset the grinding conditions to those for which the abnormal vibration of the roll grinder does not occur, and the rolling roll was ground. Then, the rolling roll ground under the reset grinding conditions was used to roll a steel strip in the cold tandem rolling mill. As a result, the steel strip was rolled without the occurrence of chattering.

[0081] To confirm the effects of Example 1, under the above-described grinding conditions, the vibration intensity was measured in a rolling-roll-grinding process in which the number of revolutions of the wheel was changed to 630 rpm and a rolling-roll-grinding process in which the number of revolutions of the wheel was unchanged from 750 rpm.

[0082] Fig. 13 is a graph showing the frequency spectrum of the measurement result of the vibration intensity. In Fig. 13, the horizontal axis represents the frequency (Hz) and the vertical axis represents the vibration intensity (m/sec^2). In Fig. 13, the solid line shows the vibration intensity for the number of revolutions of the wheel of 630 rpm, and the dashed line shows the vibration intensity for the number of revolutions of the wheel of 750 rpm.

[0083] As predicted based on the abnormal vibration map, the abnormal vibration exceeding the threshold (0.1 m/s^2) occurred in the grinding process when the number of revolutions of the wheel was 750 rpm for which the abnormal vibration was predicted to occur. In contrast, the abnormal vibration exceeding the threshold did not occur in the grinding process when the number of revolutions of the wheel was 630 rpm for which the abnormal vibration was not predicted to occur. This result confirms that the abnormal vibration can be predicted by carrying out the abnormal-vibration-predicting method for a roll grinder according to the present embodiment. It was also confirmed that when the abnormal vibration is predicted to occur, the abnormal vibration of the roll grinder can be suppressed by changing the grinding conditions to grinding conditions for which the abnormal vibration is not predicted to occur by using the abnormal vibration map.

[Example 2]

[0084] Example 2 will now be described. In Example 2, the abnormal vibration of the roll grinder was predicted using the abnormal vibration map created by a method similar to that in Example 1. In Example 2, an abnormal vibration map (discrete abnormal vibration map) related to the rigidity parameter was created as the abnormal vibration map by changing the rigidity parameter to four values. Then, the load parameter was changed to five values, and the abnormal vibration map (discrete abnormal vibration map) related to the rigidity parameter was created for each load parameter. Then, a three-dimensional abnormal vibration map (continuous abnormal vibration map) with the sum of the diameter of the rolling roll and the diameter of the grinding wheel on the X-axis and the load parameter on the Y-axis was created by connecting the upper limits and the lower limits of the ranges of the number of revolutions of the wheel in which the abnormal vibration occurs.

[0085] In the abnormal vibration map of Example 2, the sum of the diameter of the rolling roll and the diameter of the grinding wheel was used as the rigidity parameter. The abnormal vibration map related to the rigidity parameter was created by changing the sum of the diameter of the rolling roll and the diameter of the grinding wheel in the range of 1800 to 2500 mm. The wheel load current value was used as the load parameter. The wheel load current value was changed in the range of 100 to 140 A, and the abnormal vibration map related to the rigidity parameter was created for each load parameter. These maps were used to create the three-dimensional abnormal vibration map (continuous abnormal vibration map).

[0086] In Example 2, the three-dimensional abnormal vibration map created as described above was used to predict the abnormal vibration of the roll grinder. A cylindrical alumina-based grinding wheel was used for roll grinding. The current wheel diameter of the grinding wheel was 640 mm. The diameter of the rolling roll was 1302 mm.

[0087] Rough grinding was selected for the traverses in the roll grinding process. The grinding conditions were set as follows: the number of revolutions of the wheel was 730 rpm, the number of revolutions of the rolling roll was 10 rpm, and the traverse rate was 2 mm/pass. Based on the three-dimensional abnormal vibration map created as described above, the abnormal vibration was predicted to occur when the wheel load current value was 140 A. For the same rigidity parameter, the abnormal vibration was not predicted to occur when the wheel load current value was set to 100 A. Accordingly, the wheel load current value was set to 100 A and 140 A, and roll grinding was performed under two conditions while the vibration intensity was measured by the vibration meter 32.

[0088] Fig. 14 is a graph showing the measurement result of the vibration intensity. In Fig. 14, the horizontal axis represents the frequency (Hz), and the vertical axis represents the vibration intensity (m/sec^2). In Fig. 14, the solid line shows the vibration intensity for the wheel load current value of 100 A, and the dashed line shows the vibration intensity for the wheel load current value of 140 A.

[0089] As predicted based on the three-dimensional abnormal vibration map, the abnormal vibration in which the vibration intensity exceeded the threshold (0.1 m/s^2) occurred when the wheel load current value was 140 A. In contrast, the abnormal vibration exceeding the threshold did not occur in roll grinding when the wheel load current value was 100 A for which the abnormal vibration was not predicted to occur. This result confirms that the abnormal vibration can be predicted by carrying out the abnormal-vibration-predicting method for a roll grinder according to the present embodiment. It was also confirmed that when the abnormal vibration is predicted to occur, the abnormal vibration of the roll grinder can be suppressed by changing the grinding conditions to grinding conditions for which the abnormal vibration is not predicted to occur by using the abnormal vibration map.

[Example 3]

[0090] Example 3 will now be described. In Example 3, the occurrence of the abnormal vibration in the process of grinding the rolling roll was predicted by using an abnormal-vibration-prediction model whose input is the rigidity parameter of the roll grinder, the wheel rotation parameter of the grinding wheel, and the load parameter related to the load applied to the grinding wheel and whose output is the abnormal vibration information for the process of grinding the rolling roll. In Example 3, the actual data during roll grinding performed under various grinding conditions in advance was acquired as training data. The training data acquired as the actual data are as follows:

Rigidity parameter of roll grinder: Sum of diameter of rolling roll and diameter of grinding wheel
Wheel rotation parameter of grinding wheel: Number of revolutions of the wheel
Load parameter related to load applied to grinding wheel: Wheel load current value

[0091] For each grinding condition, the actual value of the abnormal vibration information was acquired by evaluating the vibration intensity exceeding the threshold (0.1 m/s^2) as NG and the vibration intensity less than or equal to the threshold as OK. With regard to the ranges of the grinding conditions collected as the training data, the range of the sum of the diameter of the rolling roll and the diameter of the grinding wheel was 1800 to 2500 mm, the range of the number of revolutions of the wheel was 8.5 to 13.5 rpm, and the range of the wheel load current value was 100 to 140 A.

[0092] The abnormal-vibration-prediction model was created by machine learning based on a machine learning model using datasets, each of which is composed of the actual input data of the rigidity parameter, the wheel rotation parameter, and the load parameter and the actual output data regarding the occurrence or non-occurrence of the abnormal vibration (OK or NG). The machine learning model used was a neural network with two intermediate layers and three nodes, and a sigmoid function was used as the activation function.

[0093] In Example 3, the abnormal-vibration-prediction model created as described above was used to predict the occurrence of the abnormal vibration in the process of newly grinding rolling rolls. Ten rolling rolls were ground. In Example 3, when the abnormal vibration was predicted to occur in a rough grinding process for a rolling roll based on the abnormal-vibration-prediction model, the rolling roll was ground after changing the grinding conditions of the roll grinder to grinding conditions determined by the guidance-information-acquisition unit as grinding conditions for which the abnormal vibration was not predicted to occur. As a result, when the ground rolling rolls were installed in a cold rolling mill to roll a steel plate, no chattering occurred in the rolling process. In contrast, other rolling rolls were ground without changing the grinding conditions of the roll grinder even when the abnormal vibration was predicted to occur based on the abnormal-vibration-prediction model. When these rolling rolls were used to roll a steel sheet, chattering occurred at an incidence of 60%.

Reference Signs List

[0094]

10	roll grinder
12	rolling roll
14	grinding wheel
16	grinding head
18	support table
20	roll chuck
22	roll rotation motor
24	tail stock
26	guide
28	guide
30	wheel rotation motor
32	vibration meter
40	control computer
42	controller
44	abnormal-vibration-predicting device
46	control unit
48	input unit
50	output unit
52	storage unit
54	data acquisition unit
56	abnormal-vibration-prediction unit
58	prediction-model-generating unit
60	guidance-information-acquisition unit
62	database
64	abnormal-vibration-prediction model
66	grinding-wheel support unit
68	roll support base
70	roll grinder
80	roll grinder
100	roll-grinding apparatus
110	roll-grinding apparatus

Claims

1. An abnormal-vibration-predicting method for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting method comprising:

an acquisition step of acquiring a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and
a prediction step of predicting an occurrence of an abnormal vibration in a process of grinding the rolling roll by using the rigidity parameter and the wheel rotation parameter.

2. The abnormal-vibration-predicting method for a roll grinder according to Claim 1, wherein the rigidity parameter includes a distance between a rotation center of the rolling roll and a rotation center of the grinding wheel or a sum of a diameter of the rolling roll and a diameter of the grinding wheel.

3. The abnormal-vibration-predicting method for a roll grinder according to Claim 1, wherein, in the acquisition step, a load parameter related to a load applied to the grinding wheel is further acquired, and
wherein, in the prediction step, the occurrence of the abnormal vibration in the process of grinding the rolling roll is predicted by using the rigidity parameter, the wheel rotation parameter, and the load parameter.

4. The abnormal-vibration-predicting method for a roll grinder according to Claim 3, wherein the load parameter includes a load current value of an electric motor that rotates the grinding wheel.

5. An abnormal-vibration-predicting method for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting method comprising:

an acquisition step of acquiring input data including a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and
a prediction step of predicting an occurrence of an abnormal vibration in a process of grinding the rolling roll by using an abnormal-vibration-prediction model whose input is the input data and whose output is abnormal vibration information for the process of grinding the rolling roll.

6. The abnormal-vibration-predicting method for a roll grinder according to Claim 5, wherein the rigidity parameter includes a distance between a rotation center of the rolling roll and a rotation center of the grinding wheel or a sum of a diameter of the rolling roll and a diameter of the grinding wheel.

7. The abnormal-vibration-predicting method for a roll grinder according to Claim 5, wherein the input data acquired in the acquisition step includes the rigidity parameter, the wheel rotation parameter, and a load parameter related to a load applied to the grinding wheel.

8. The abnormal-vibration-predicting method for a roll grinder according to Claim 7, wherein the load parameter includes a load current value of an electric motor that rotates the grinding wheel.

9. A rolling-roll-grinding method using the abnormal-vibration-predicting method for a roll grinder according to any one of Claims 1 to 8,
wherein, when the abnormal vibration is predicted to occur in the prediction step, grinding conditions of the roll grinder are changed to grinding conditions for which the abnormal vibration is not predicted to occur.

10. A metal-strip-rolling method comprising:
rolling a metal strip in a rolling mill in which a rolling roll is installed, the rolling roll being ground by the rolling-roll-grinding method according to Claim 9.

11. An abnormal-vibration-predicting device for a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates, the abnormal-vibration-predicting device comprising:

a data acquisition unit that acquires input data including a rigidity parameter related to a rigidity of the roll grinder and a wheel rotation parameter related to a rotational speed of the grinding wheel; and
an abnormal-vibration-prediction unit that predicts an occurrence of an abnormal vibration of the roll grinder by using an abnormal-vibration-prediction model whose input is the input data and whose output is abnormal vibration information.

12. The abnormal-vibration-predicting device for a roll grinder according to Claim 11, wherein the input data acquired by the data acquisition unit includes the rigidity parameter, the wheel rotation parameter, and a load parameter related to a load applied to the grinding wheel.

13. The abnormal-vibration-predicting device for a roll grinder according to Claim 11 or 12, further comprising a guidance-information-acquisition unit that determines the input data for which the abnormal vibration does not occur by using the abnormal-vibration-prediction model.

14. A roll-grinding apparatus comprising:

a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates; and
the abnormal-vibration-predicting device for a roll grinder according to Claim 11 or 12.

15. A roll-grinding apparatus comprising:

a roll grinder that grinds an outer peripheral surface of a rolling roll with a grinding wheel while the rolling roll rotates; and
the abnormal-vibration-predicting device for a roll grinder according to Claim 13.

FIG. 1

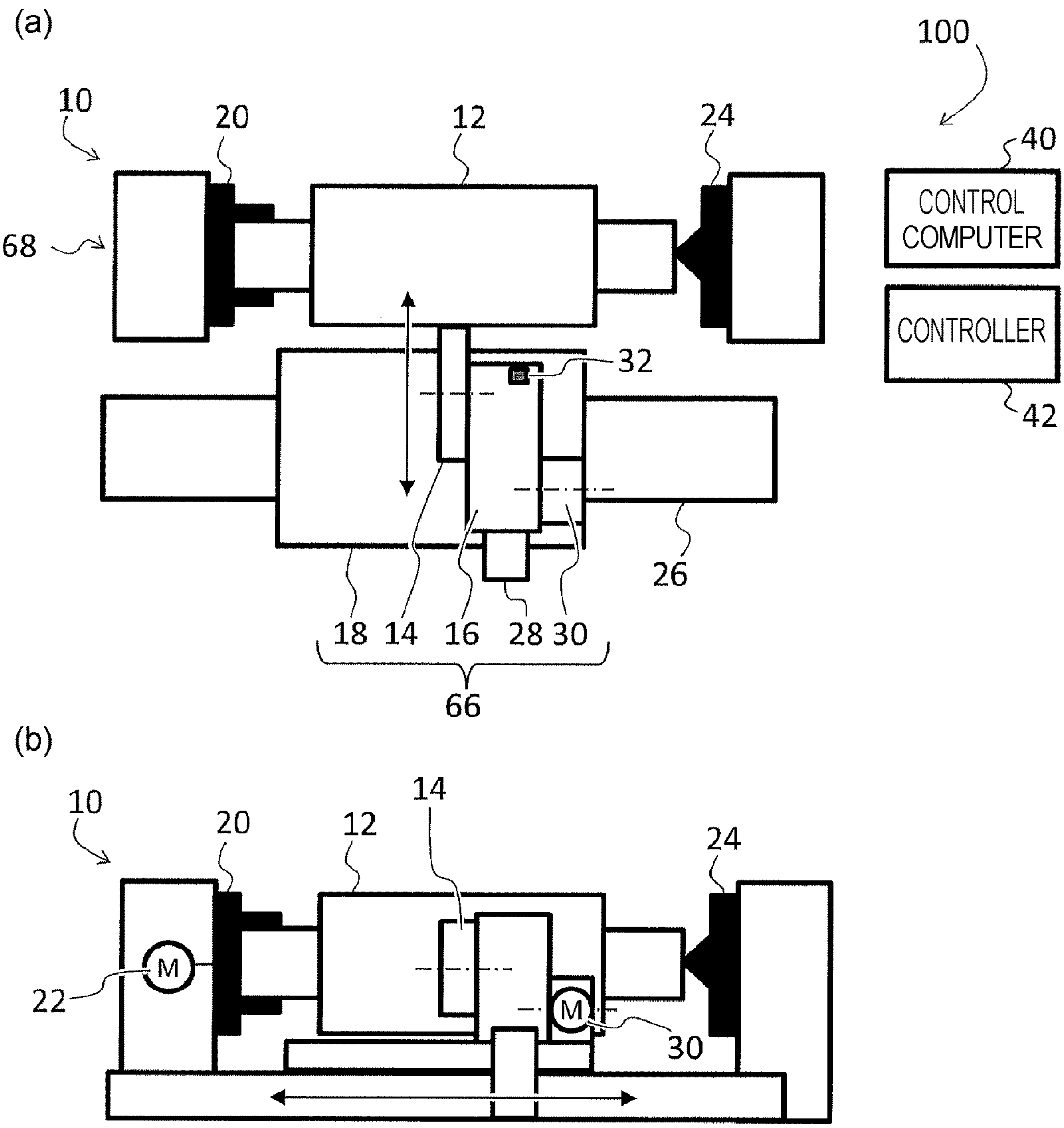

(a)
100
10
20
12
24
40
CONTROL COMPUTER
68
CONTROLLER
32
42
26
18 14 16 28 30
66
(b)
10
20
12
14
24
22
M
M
30

FIG. 2

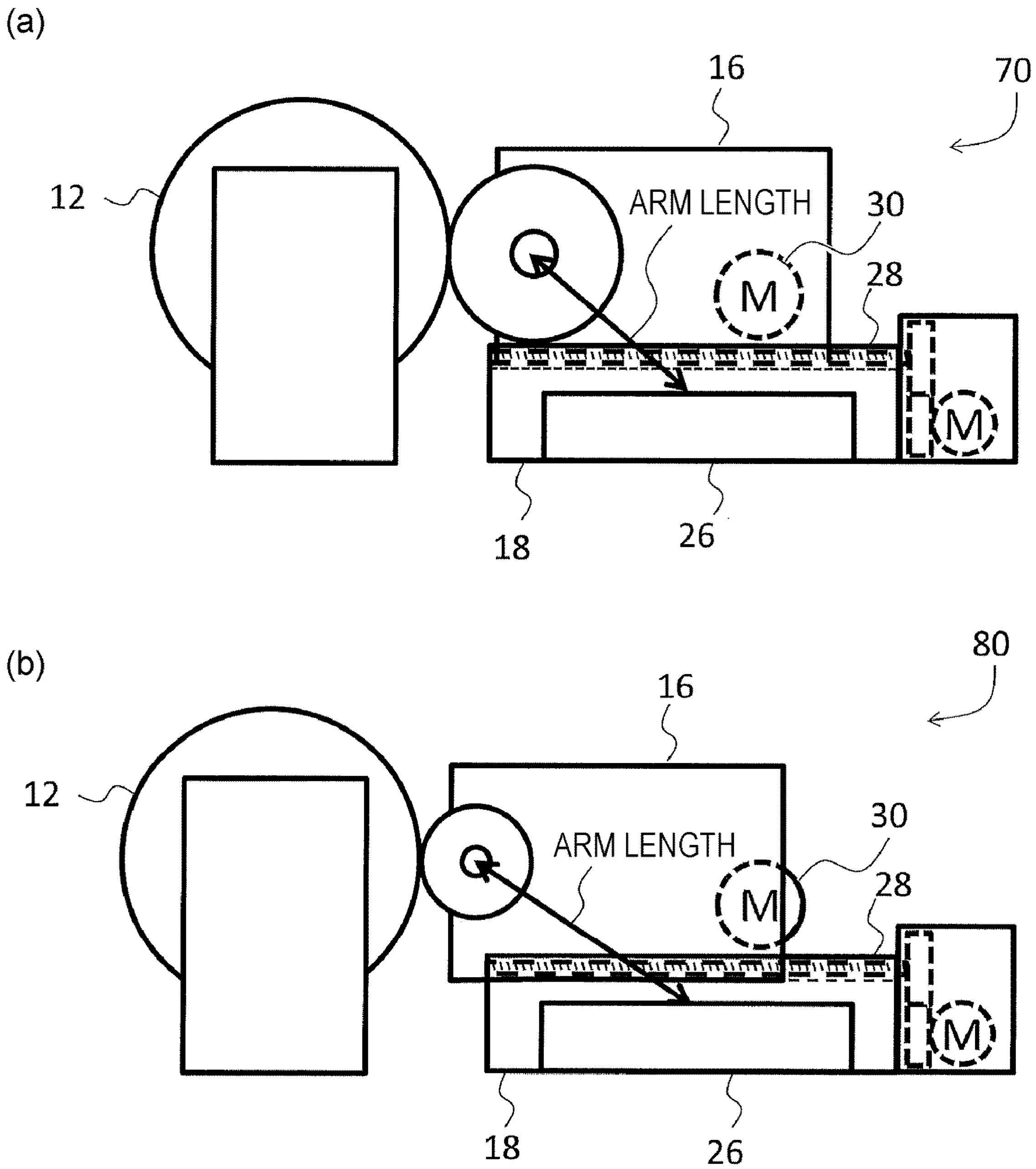

(a)
16
70
12
ARM LENGTH
30
M
28
M
18
26
(b)
80
16
12
ARM LENGTH
30
M
28
M
18
26

FIG. 3

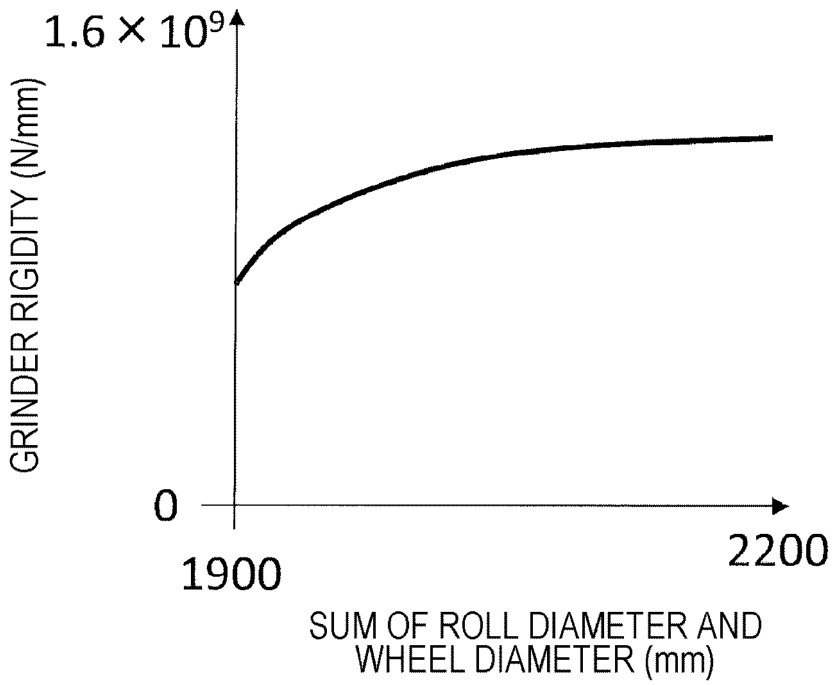

1.6 × 10^9
GRINDER RIGIDITY (N/mm)
0
1900
2200
SUM OF ROLL DIAMETER AND
WHEEL DIAMETER (mm)

FIG. 4

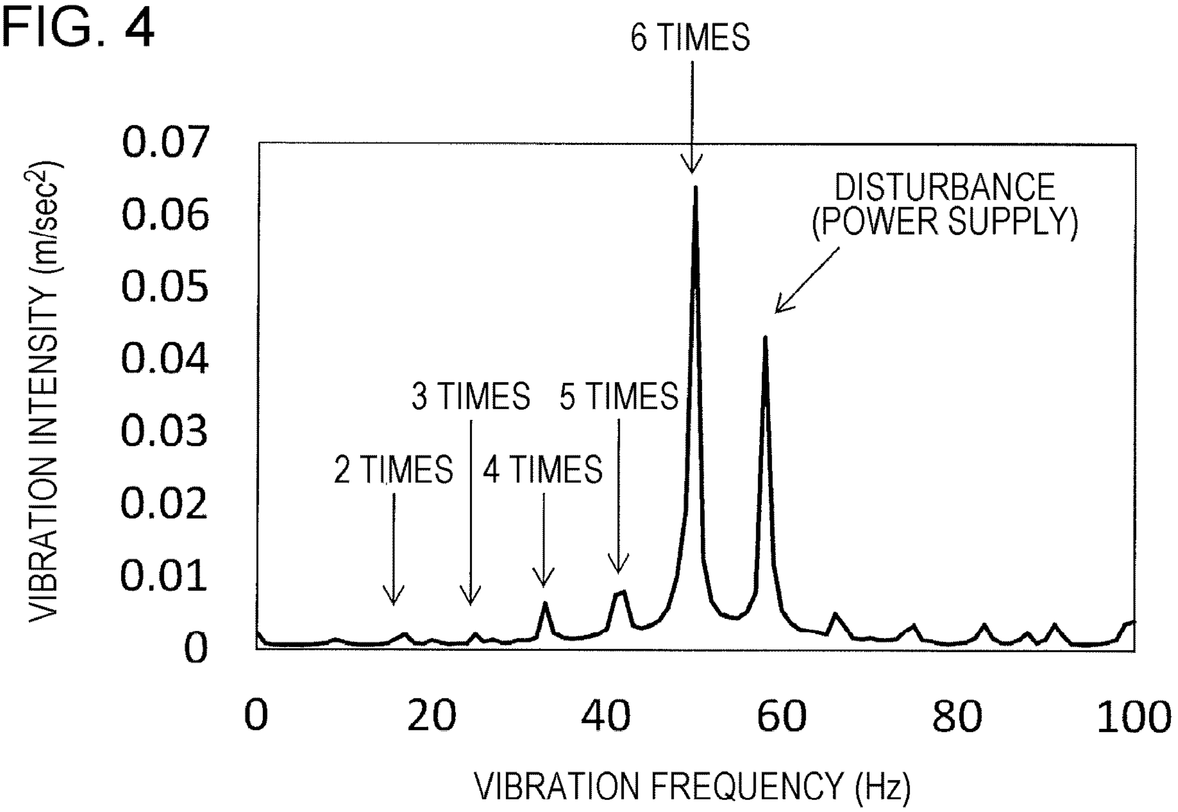

6 TIMES
DISTURBANCE
(POWER SUPPLY)
3 TIMES
5 TIMES
2 TIMES
4 TIMES
VIBRATION INTENSITY (m/sec²)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
VIBRATION FREQUENCY (Hz)

FIG. 5

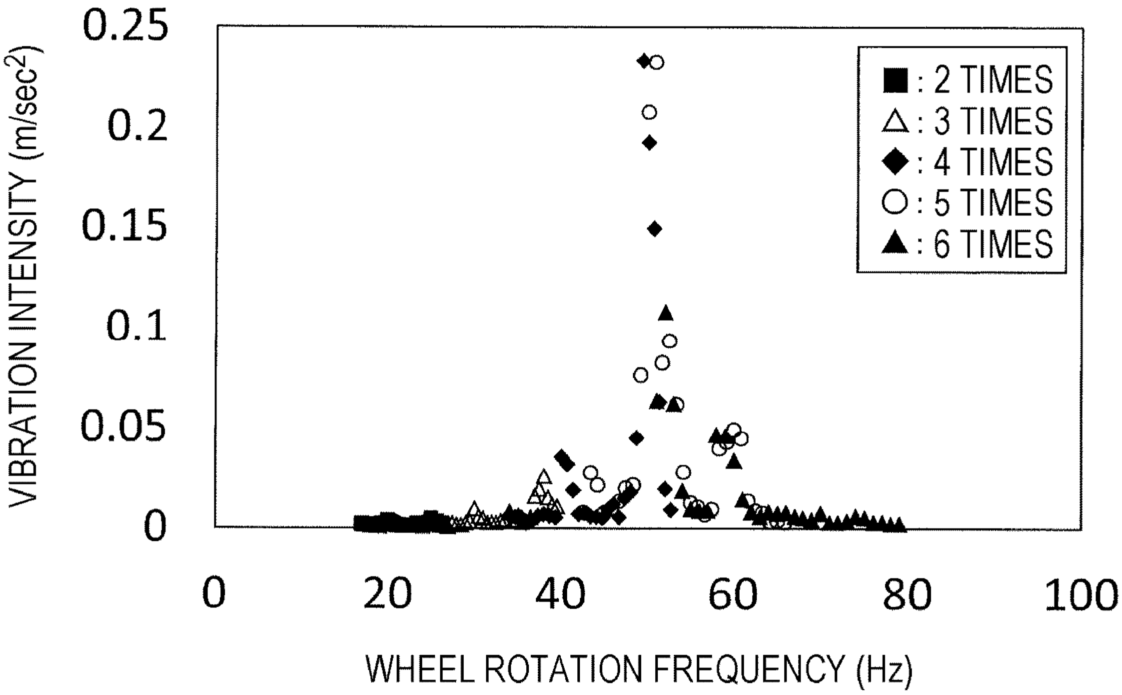

0.25
0.2
0.15
0.1
0.05
0
VIBRATION INTENSITY (m/sec^2)
■ : 2 TIMES
△ : 3 TIMES
◆ : 4 TIMES
○ : 5 TIMES
▲ : 6 TIMES
0
20
40
60
80
100
WHEEL ROTATION FREQUENCY (Hz)

FIG. 6

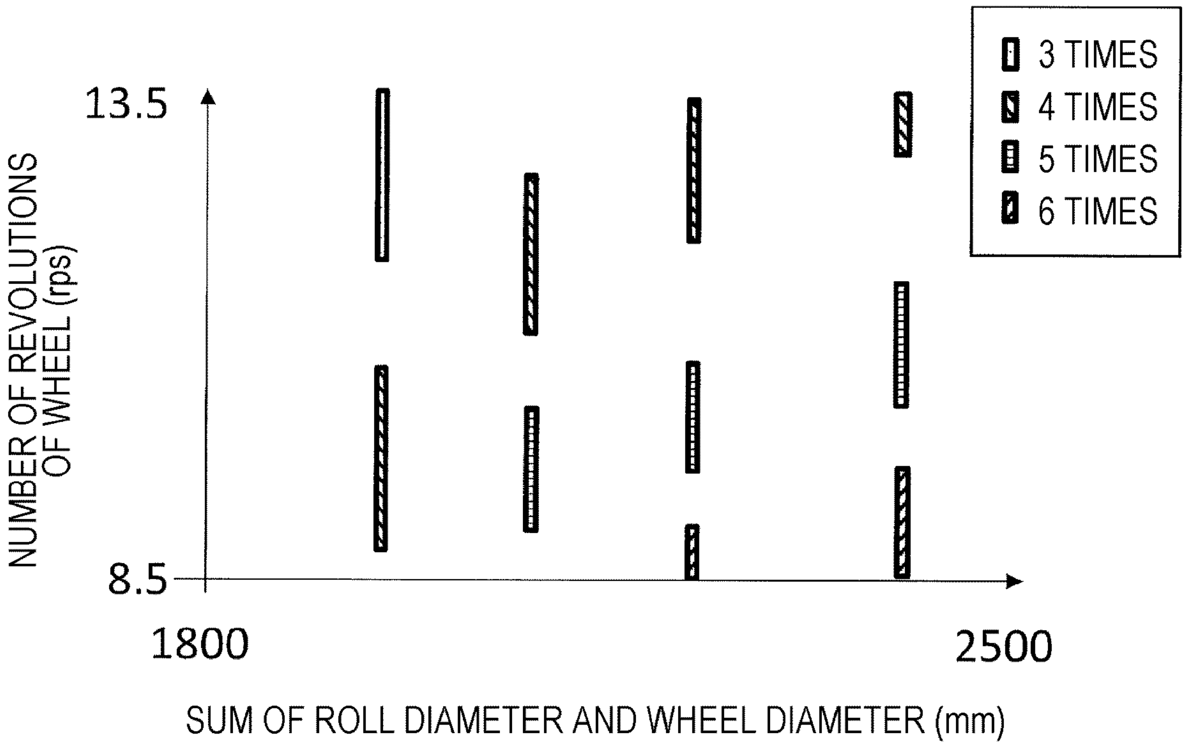

3 TIMES
4 TIMES
5 TIMES
6 TIMES
13.5
8.5
NUMBER OF REVOLUTIONS OF WHEEL (rps)
1800
2500
SUM OF ROLL DIAMETER AND WHEEL DIAMETER (mm)

FIG. 7

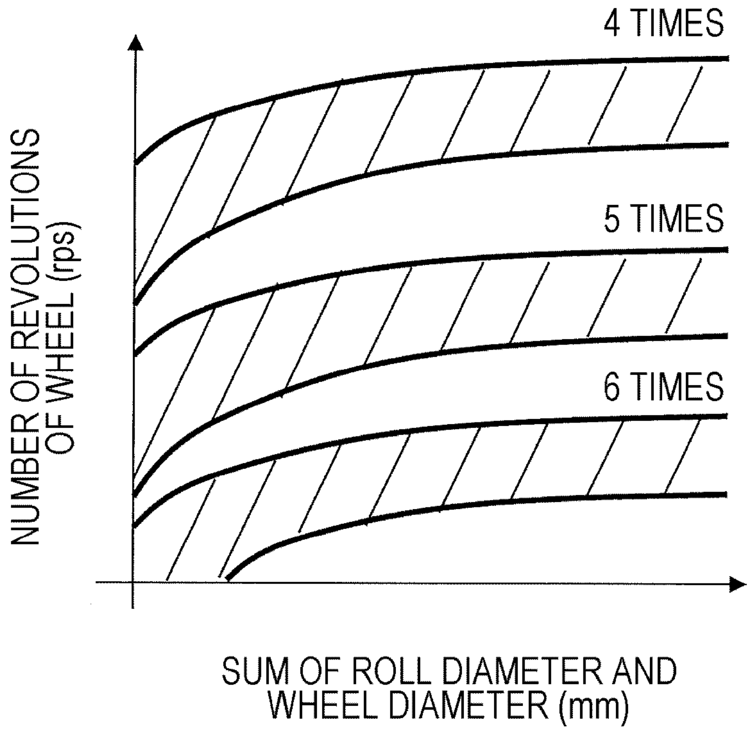

4 TIMES
5 TIMES
6 TIMES
NUMBER OF REVOLUTIONS OF WHEEL (rps)
SUM OF ROLL DIAMETER AND WHEEL DIAMETER (mm)

FIG. 8

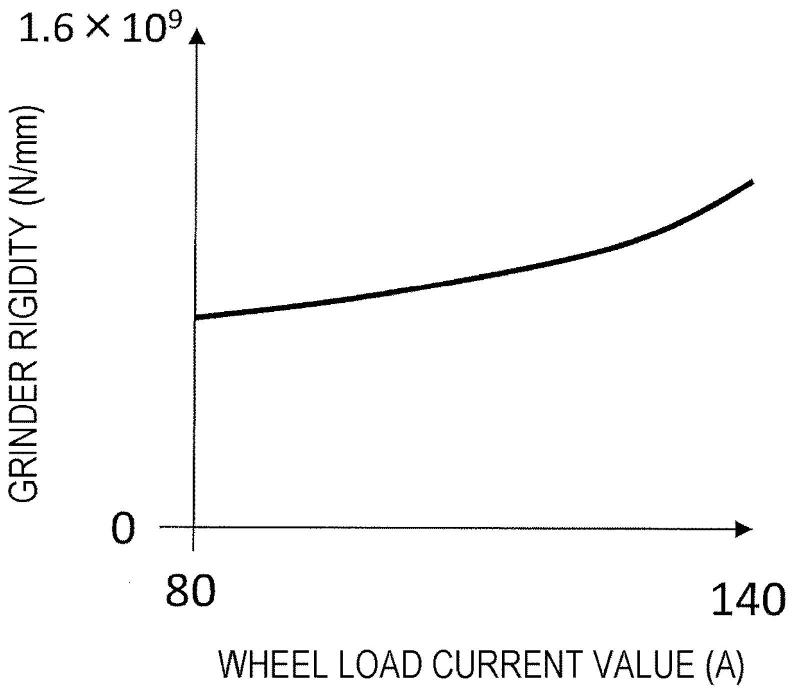

1.6 × 10⁹
0
GRINDER RIGIDITY (N/mm)
80
140
WHEEL LOAD CURRENT VALUE (A)

FIG. 9

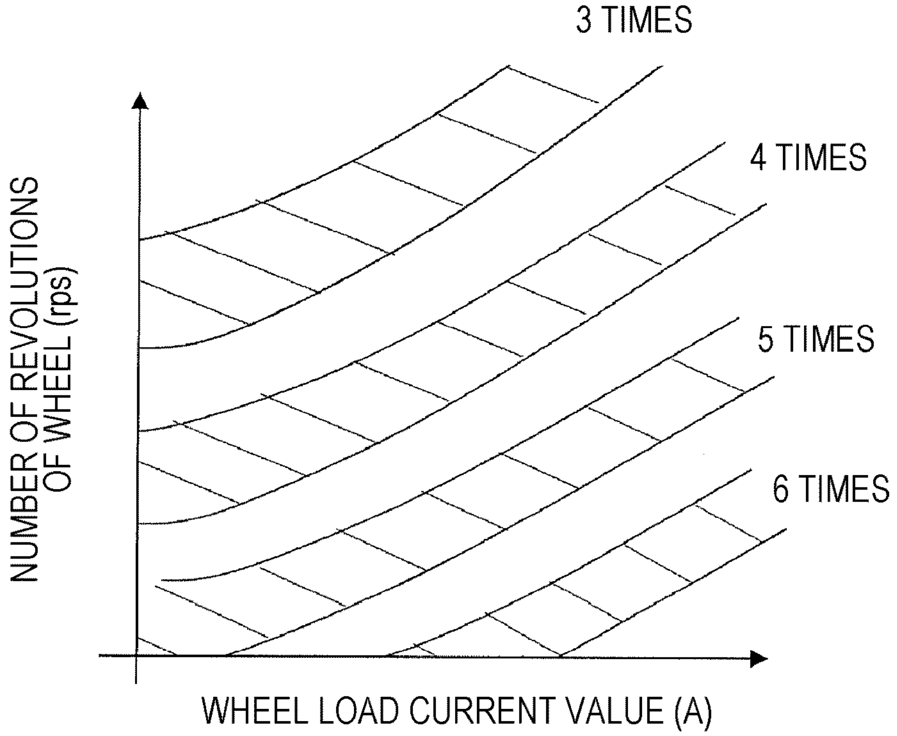

3 TIMES
4 TIMES
5 TIMES
6 TIMES
NUMBER OF REVOLUTIONS OF WHEEL (rps)
WHEEL LOAD CURRENT VALUE (A)

FIG. 10

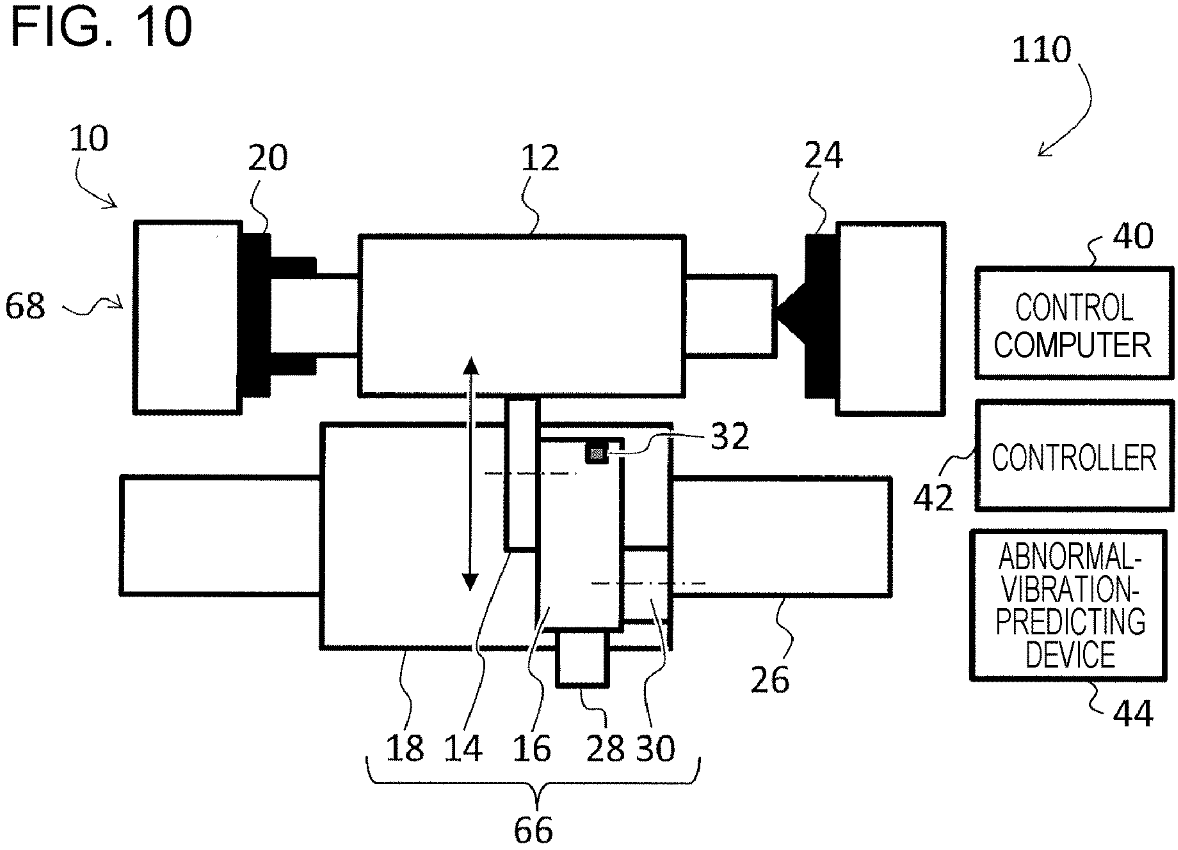

110
10
20
12
24
68
40
CONTROL COMPUTER
CONTROLLER
42
ABNORMAL-VIBRATION-PREDICTING DEVICE
44
32
26
18 14 16 28 30
66

FIG. 11

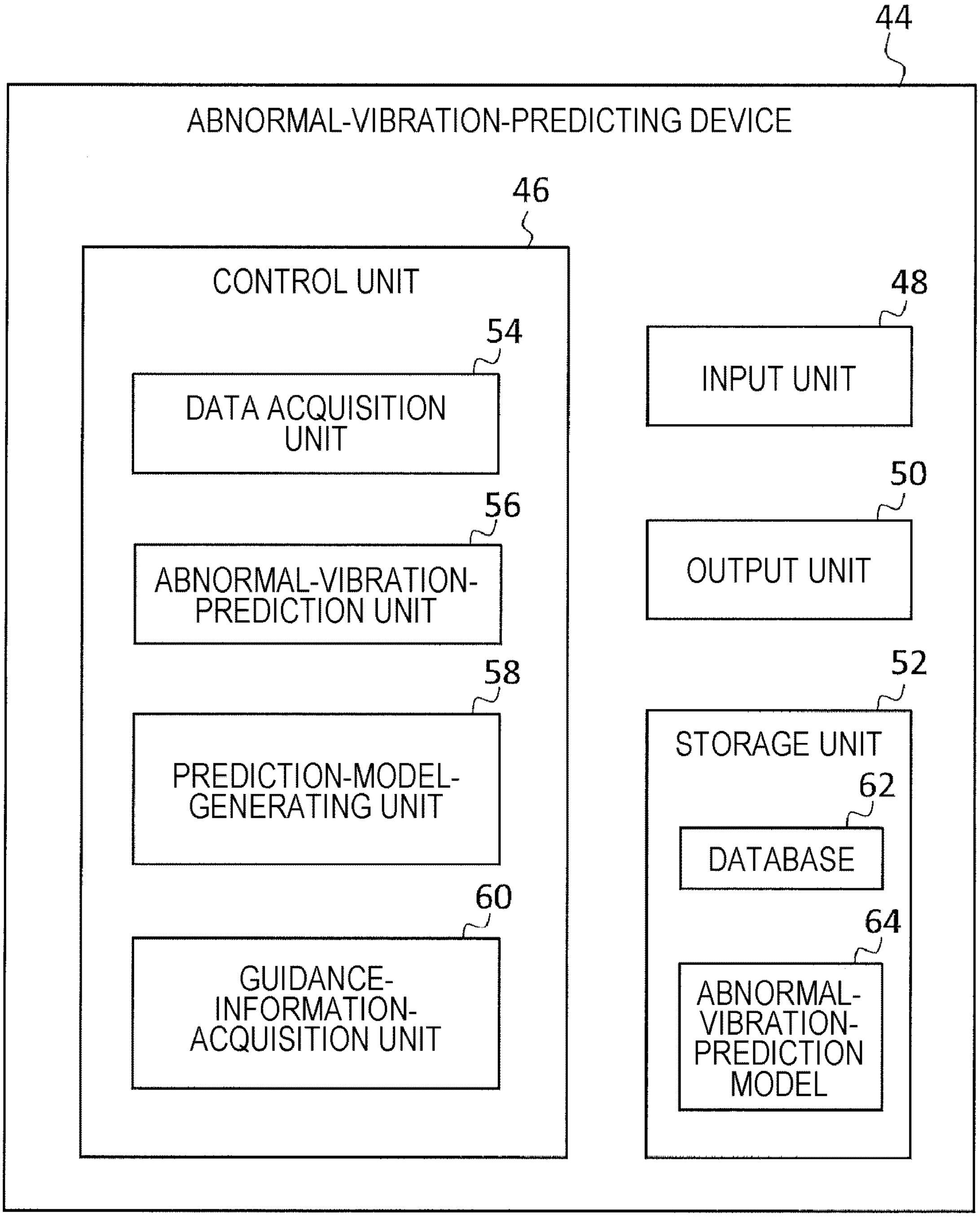

44
ABNORMAL-VIBRATION-PREDICTING DEVICE
46
CONTROL UNIT
54
DATA ACQUISITION UNIT
56
ABNORMAL-VIBRATION-PREDICTION UNIT
58
PREDICTION-MODEL-GENERATING UNIT
60
GUIDANCE-INFORMATION-ACQUISITION UNIT
48
INPUT UNIT
50
OUTPUT UNIT
52
STORAGE UNIT
62
DATABASE
64
ABNORMAL-VIBRATION-PREDICTION MODEL

FIG. 12

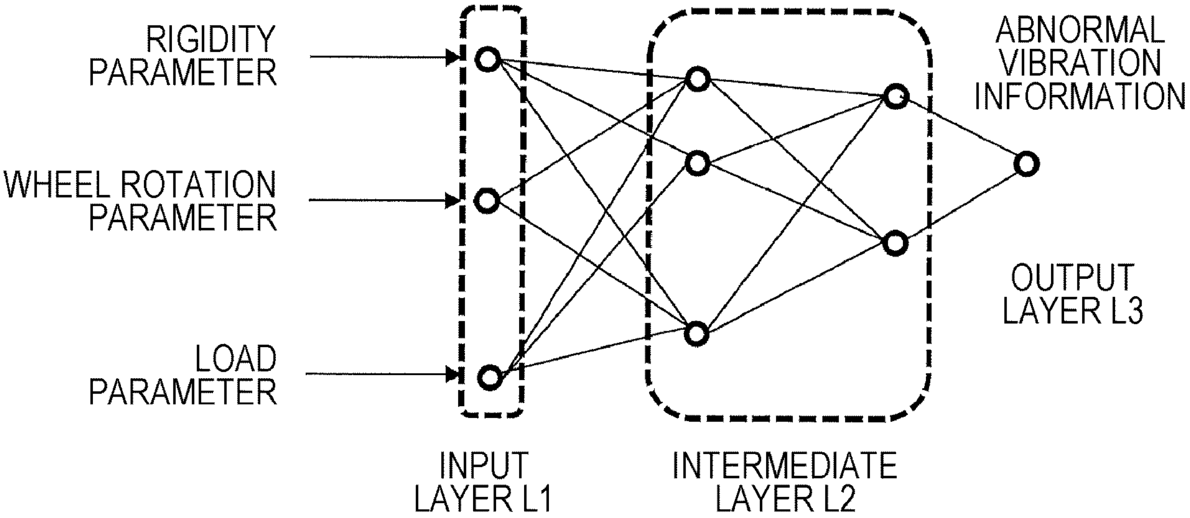

RIGIDITY PARAMETER
WHEEL ROTATION PARAMETER
LOAD PARAMETER
INPUT LAYER L1
INTERMEDIATE LAYER L2
ABNORMAL VIBRATION INFORMATION
OUTPUT LAYER L3

FIG. 13

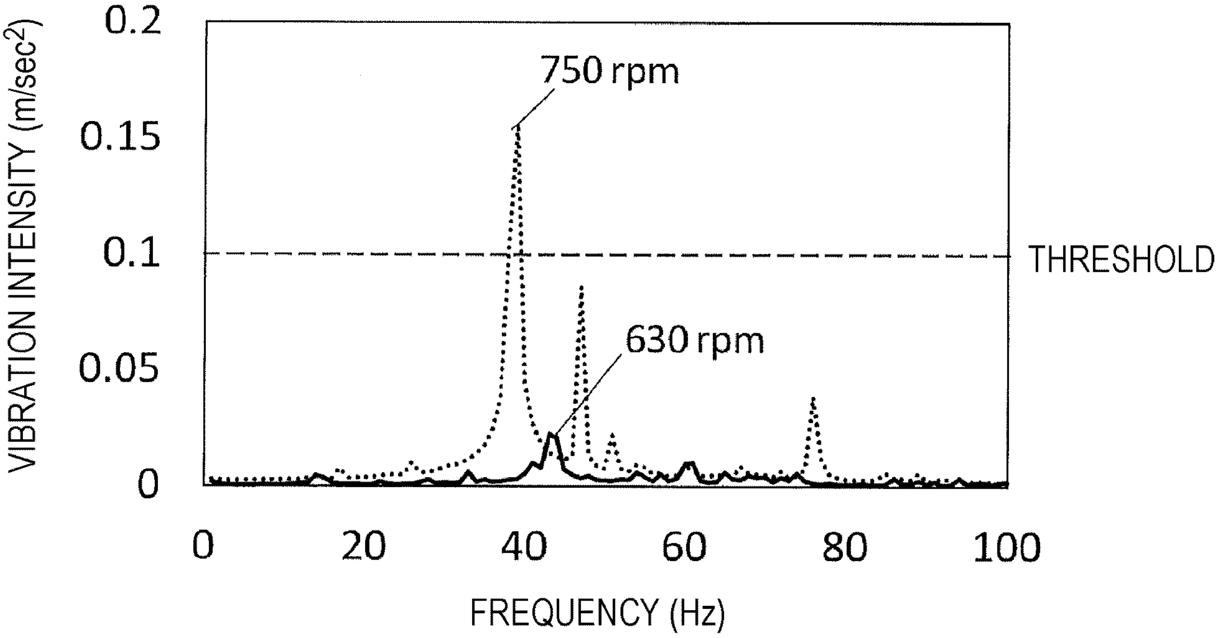
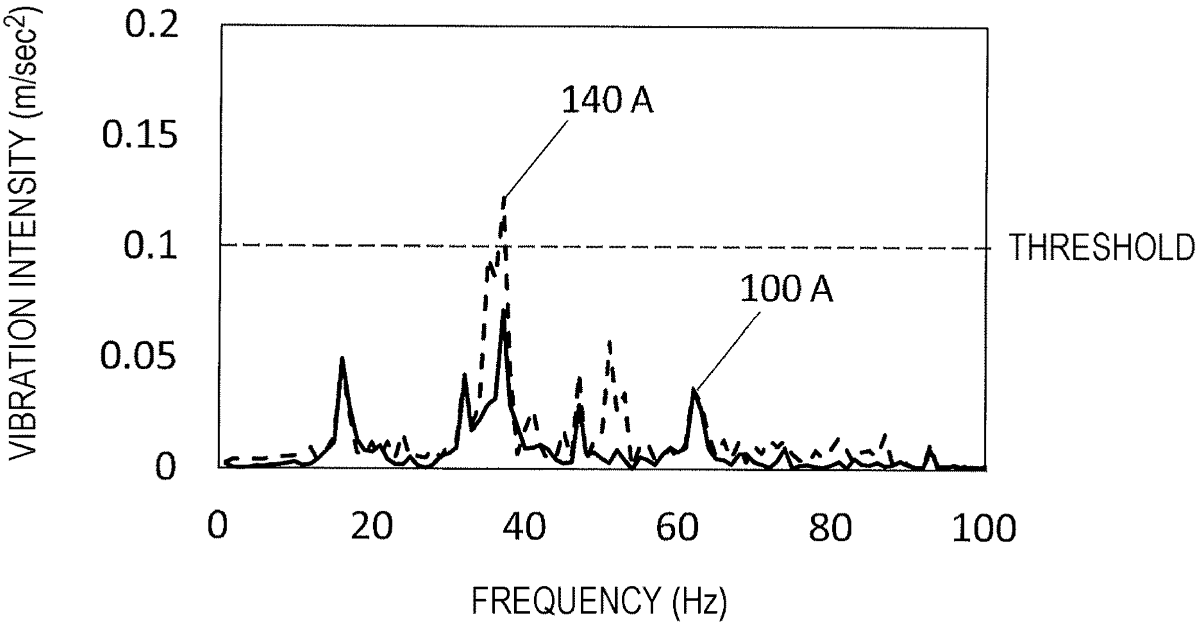

VIBRATION INTENSITY (m/sec2)
0.2
0.15
0.1
0.05
0
750 rpm
630 rpm
THRESHOLD
0
20
40
60
80
100
FREQUENCY (Hz)

FIG. 14


VIBRATION INTENSITY (m/sec2)
0.2
0.15
0.1
0.05
0
140 A
THRESHOLD
100 A
0
20
40
60
80
100
FREQUENCY (Hz)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/004277

A. CLASSIFICATION OF SUBJECT MATTER

B24B 49/10(2006.01)i; ***B21B 38/00***(2006.01)i; ***B24B 5/04***(2006.01)i; ***B24B 49/16***(2006.01)i
FI: B24B49/10; B24B49/16; B24B5/04; B21B38/00 D

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)

B24B49/10; B21B38/00; B24B5/04; B24B49/16

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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	WO 2022/049975 A1 (JFE STEEL CORP) 10 March 2022 (2022-03-10)	1-15
A	JP 2018-25979 A (JTEKT CORP) 15 February 2018 (2018-02-15)	1-15
A	JP 2020-69596 A (MITSUI HIGH TEC) 07 May 2020 (2020-05-07)	1-15

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
14 April 2023	**25 April 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **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/JP2023/004277

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2022/049975 A1	10 March 2022	(Family: none)	
JP 2018-25979 A	15 February 2018	US 2018/0045613 A1 DE 102017117991 A1 CN 107728586 A	
JP 2020-69596 A	07 May 2020	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 52056468 A **[0006]**