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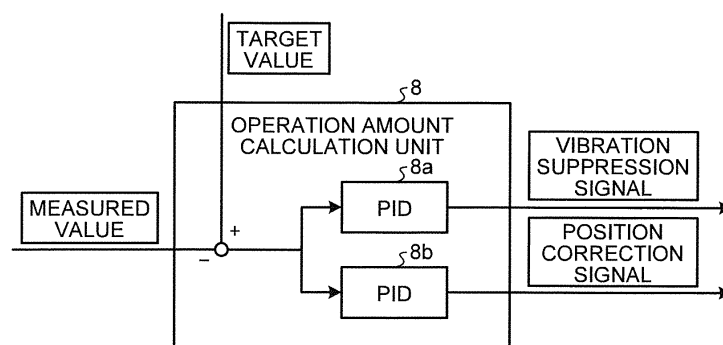
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(54) **METAL STRIP STABILIZER, METHOD FOR MANUFACTURING HOT DIPPED METAL STRIP, AND METAL STRIP**

(57) Provided is a metal strip stabilizer with which loss in vibration suppression performance caused by an induced current between a vibration suppression coil and a position correction coil may be prevented. The metal strip stabilizer according to the present invention includes: a non-contact displacement sensor that measures displacement of a metal strip 2 during online running; a control unit 5 that outputs a vibration suppression signal and a position correction signal after a signal is input from the non-contact displacement sensor; a vibration suppression coil 7a that generates a magnetic force in accordance with the vibration suppression signal output

from the control unit 5; a position correction coil 7b that generates a magnetic force in accordance with the position correction signal output from the control unit 5, a winding number thereof being larger than a winding number of the vibration suppression coil 7a; a core 6 around which the vibration suppression coil 7a and the position correction coil 7b are wound concentrically and that induces the magnetic force generated by the vibration suppression coil 7a and the position correction coil 7b to the metal strip 2; and a counter induced current coil 13a that is disposed in series to an electric circuit supplying electricity to the position correction coil 7b.

FIG.4



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Description

FIELD

5 **[0001]** The present invention relates to a metal strip stabilizer, a method of manufacturing a hot-dip coated metal strip using that, and a metal strip manufactured by using that.

BACKGROUND

10 **[0002]** In a metal-strip-manufacturing line, suppressing vibration or warp of a metal strip to maintain a stable metal strip pass line contributes to improve not only quality of the metal strip but also efficiency of the manufacturing line.

[0003] For example, in a manufacturing line for a hot-dip coated metal strip, there is a process of adhering molten metal to a surface of a metal strip by passing and immersing the metal strip through a hot-dip metal bath. In this process, in order to suppress generation of unevenness in an amount of the adhering molten metal, an adjustment is performed to shake off the molten metal excessively adhering to the metal strip by discharging wiping gas from a gas wiper provided subsequent to the hot-dip metal bath.

[0004] In this adjustment of the molten metal, it is necessary to discharge the wiping gas from the gas wiper so that pressure is applied to obverse and reverse surfaces of the metal strip uniformly in a plate width direction. Therefore, when a distance between the gas wiper and the metal strip is not constant, that is, in cases where the metal strip is vibrating, the metal strip is warping, or the pass line of the metal strip is leaning to either one of the obverse and reverse surfaces, the pressure of the wiping gas is not uniform in the plate width direction or in a direction in which the metal strip passes. As a result, a problem occurs that unevenness in the amount of the adhering molten metal occurs between the obverse and reverse surfaces of the metal strip, in the plate width direction, or in the direction in which the metal strip passes.

25 **[0005]** As a method of solving such a problem, a technique is known that stabilizes the metal strip pass line by suppressing the warp or the vibration of a metal strip in a non-contact manner by using an electromagnet. For example, a method is known that disposes a pair of electromagnets to face each other with respect to a pass line moving a metal strip and makes attraction forces of the electromagnets, while being switched alternatively in accordance with a signal from a position detector disposed separately, act on the metal strip (see Patent Document 1).

30 **[0006]** The above-described metal strip vibration control using the electromagnets requires responsiveness of the electromagnets, and the warp correction and the pass line correction require the attraction forces of the electromagnets. It should be noted that a combination of warp correction and pass line correction is hereinafter called the position correction. That is, in order to realize suppressing of vibration and correction of position of a metal strip simultaneously, mutually contradictory characteristics of responsiveness and attraction force are necessary. That is because responsiveness of the electromagnet becomes worsened if the winding number of a coil is increased to increase attraction force of the electromagnet, and on the other hand, attraction force of the electromagnet decreases if the winding number is decreased to improve responsiveness of the electromagnet.

[0007] Then, to address this problem, proposed is a technique for controlling a metal strip in a non-contact manner by using electromagnets having two independent systems of coils, one is for vibration control and the other is for position correction (see Patent Document 2). According to the technique, since vibration control is possible by a vibration suppression coil having a smaller winding number, and warp correction and pass line correction is possible by a position correction coil having a larger winding number, it is possible to perform a control while establishing both vibration-control performance and position-correction performance.

45 Citation List

Patent Literature

[0008]

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Patent Literature 1: Japanese Laid-open Patent Publication No. 02-62355

Patent Literature 2: Japanese Laid-open Patent Publication No. 2004-124191

Summary

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Technical Problem

[0009] However, in the above-explained technique for controlling a metal strip in a non-contact manner by using

independent electromagnets having two systems of coils, due to mutual induction between the vibration suppression coil and the position correction coil, a change in an electric current in the vibration suppression coil affects an electric current in the position correction coil, and in contrast, a change in the electric current in the position correction coil affects the electric current in the vibration suppression coil. As a result of this, the above-described control technique had a problem that an attraction force different from an attraction force required by a control signal was generated. That is, although the metal strip stabilizer using the electromagnets having two independent systems of coils, one for suppressing vibration and the other for correcting position, can perform the control with establishing both vibration-control performance and position correction performance, there was a problem that a mutual induction between the vibration suppression coil and the position correction coil decreased the vibration suppression performance.

[0010] The present invention has been made in view of the above-mentioned circumstances and an object thereof is to provide a metal strip stabilizer which is capable of avoiding lowering of vibration suppression performance caused by an induced current between a vibration suppression coil and a position correction coil and a method of manufacturing a hot-dip coated metal strip using that.

Solution to Problem

[0011] To solve the problem described above and achieve the object, a metal strip stabilizer according to the present invention includes: a non-contact displacement sensor that measures displacement of a metal strip during online running; a control unit that outputs a vibration suppression signal for suppressing vibration of the metal strip and a position correction signal for correcting a position of the metal strip after a signal is input from the non-contact displacement sensor; a first coil that generates a magnetic force in accordance with the vibration suppression signal output from the control unit; a second coil that generates a magnetic force in accordance with the position correction signal output from the control unit, a winding number of the second coil being larger than a winding number of the first coil; a core around which the first coil and the second coil are wound concentrically and that induces the magnetic force generated by the first coil and the second coil to the metal strip; and a third coil that is disposed in series to an electric circuit supplying electricity to the second coil.

Advantageous Effects of Invention

[0012] According to the metal strip stabilizer of the present invention and the method of manufacturing a hot-dip coated metal strip, it is possible to avoid lowering of the vibration suppression performance caused by an induced current between the vibration suppression coil and the position correction coil.

Brief Description of Drawings

[0013]

FIG. 1 is a schematic view showing a configuration of a metal strip stabilizer according to an embodiment of the present invention.

FIG. 2 is a schematic view showing an example of an electromagnet used in the metal strip stabilizer according to the embodiment of the present invention.

FIG. 3 is a block diagram showing a configuration of a control unit in the metal strip stabilizer according to the embodiment of the present invention.

FIG. 4 is a block diagram explaining an example of a configuration of an operation amount calculation unit.

FIG. 5 is a schematic view showing an electric circuit of the electromagnet in the metal strip stabilizer according to the embodiment of the present invention.

FIG. 6 is a schematic view showing a part of a commonly used manufacturing line for a hot-dip coated metal strip.

FIG. 7 is an enlarged view showing the vicinity of a gas wiper of the manufacturing line for a hot-dip coated metal strip.

FIG. 8 is a graph showing data measured by a metal strip stabilizer according to a comparative example.

FIG. 9 is a graph showing data measured by the metal strip stabilizer according to the embodiment of the present invention.

FIG. 10 is a graph in which magnitudes of noise included in the measured data shown in FIG. 8 and the measured data shown in FIG. 9 are compared.

Description of Embodiment

[0014] Hereinafter, a metal strip stabilizer according to an embodiment of the present invention will be explained with reference to the drawings.

[0015] FIG. 1 is a schematic view showing a configuration of a metal strip stabilizer 1 according to the embodiment of the present invention. As shown in FIG. 1, the stabilizer 1 according to the embodiment of the present invention includes a pair of electromagnets 3a and 3b disposed to face each other and to put therebetween a metal strip 2 running in a direction of an arrow A in the drawing, a non-contact displacement sensor 4 disposed in the vicinity of the electromagnets 3a and 3b, and a control unit 5 controlling the electromagnets 3a and 3b based on input from the non-contact displacement sensor 4.

[0016] FIG. 2 is a schematic view showing an example of the electromagnet 3a used in the metal strip stabilizer 1 according to the embodiment of the present invention. It should be noted that herein only the electromagnet 3a for use of an obverse surface of the metal strip 2 will be explained, the following explanation is effective for the electromagnet 3b for use of a reverse surface of the metal strip 2. The electromagnet 3a shown in FIG. 2 is configured as a concentric coil consisting of a coil 7a and a coil 7b constituted by winding two coils concentrically around a core 6. Two coils 7a and 7b are configured by changing their winding numbers, one of the coils 7a and 7b having a smaller winding number is the vibration suppression coil 7a and the other one having a larger winding number is the position correction coil 7b.

[0017] Although high responsiveness is required for the vibration suppression coil 7a in order to be capable of fully following a vibration frequency (usually, a natural vibration frequency of bending or warp of a metal strip) of the target metal strip 2, but, for suppressing vibration at a natural frequency of a metal strip, a large attraction force is not required. Therefore, the winding number of the vibration suppression coil 7a is configured to be smaller than that of the position correction coil 7b.

[0018] On the other hand, although high responsiveness is not required for the position correction coil 7b, it is desirable to be capable of generating a larger attraction force with a smaller current. Therefore, it is preferable that the winding number of the position correction coil 7b is large within a range in which a size and a value of electric resistance of the electromagnet 3a are not too large.

[0019] In the following, relationship between the winding number of a coil and responsiveness and attraction force of an electromagnet will be explained.

[0020] The movement of the electromagnet is represented by an equation (1):

$$e = L di/dt + Ri \quad (1)$$

where e indicates an applied voltage, i indicates an electric current flowing in the coil, L indicates an inductance of the coil, and R indicates resistance of the coil.

[0021] As shown in the equation (1), the electric current i flowing in the coil is in the primary delay system relative to the applied voltage e, and its time constant T is represented by an equation (2):

$$T = L/R \quad (2)$$

where the inductance L of the coil is in proportion with the square of a winding number N of the coil, and the resistance R of the coil is in proportion with the winding number N of the coil. Therefore, according to the equation (2), the time constant T is supposed to be in proportion with the winding number N of the coil. This means that, the larger the winding number of the coil is, the larger the time constant becomes and the more responsiveness decreases.

[0022] On the other hand, as shown in an equation (3), the attraction force F of the electromagnet is in proportion with the square of the winding number N of the coil and the square of the electric current i flowing in the coil.

$$F \propto N^2 i^2 \quad (3)$$

Therefore, for obtaining the larger attraction force with the same current, it is advantageous to increase the winding number N of the coil.

[0023] The above indicates that, although it is preferable to decrease the winding number N of the coil to improve responsiveness, it is preferable to increase the winding number N of the coil to intensify an attraction force. Therefore, in the electromagnet 3a according to the embodiment of the present invention, the winding number of the vibration suppression coil 7a which needs the high responsiveness but no large attraction force is configured to be smaller than the winding number of the position correction coil 7b. On the other hand, the winding number of the position correction coil 7b which needs the large attraction force but no high responsiveness is configured to be larger than the winding

number of the vibration suppression coil 7a.

[0024] FIG. 3 is a block diagram showing a configuration of the control unit 5 in the metal strip stabilizer 1 according to the embodiment of the present invention. As shown in FIG. 3, the control unit 5 of the metal strip stabilizer 1 according to the embodiment of the present invention includes an operation amount calculation unit 8, obverse/reverse distribution units 9a and 9b, amplifiers 10a, 10b, 10c, and 10d, and inductors 11a and 11b.

[0025] The operation amount calculation unit 8 performs a so-called PID control such as proportion, differentiation, and integration, etc. to a difference signal between a measured value of displacement of a metal strip by the non-contact displacement sensor 4 and a target value set by an input unit 12, and thereafter outputs a vibration suppression signal and a position correction signal. FIG. 4 is a block diagram explaining an example of a configuration of the operation amount calculation unit 8.

[0026] As shown in FIG. 4, the operation amount calculation unit 8 includes a vibration suppression PID control unit 8a and a position correction PID control unit 8b. The vibration suppression PID control unit 8a is a calculation means to which a difference signal between a measured value and a target value of displacement of a metal strip is input and from which a vibration suppression signal is output, and the position correction PID control unit 8b is a calculation means to which a difference signal between a measured value and a target value of displacement of the metal strip and from which a position correction signal is output.

[0027] Herein the calculation by the vibration suppression PID control unit 8a is responsiveness-focused calculation, and the calculation by the position correction PID control unit 8b is static-attraction-force-focused calculation. That is, the calculation by the vibration suppression PID control unit 8a is set so that a gain for a high frequency component included in an input signal is larger, and the calculation by the position correction PID control unit 8b is set so that a gain for a low frequency component included in an input signal is larger. For example, by setting a derivative gain larger in the vibration suppression PID control unit 8a and setting an integral gain larger in the position correction PID control unit 8b, the above-described setting is realized.

[0028] The high frequency and the low frequency mentioned here mean relatively high or low in comparison between the vibration suppression PID control unit 8a and the position correction PID control unit 8b. In addition, according to the above-described configuration, the fact that the vibration suppression signal includes a lot of the high frequency component and the position correction signal includes a lot of low frequency component means that an average value of the frequency components of the vibration suppression signal is higher than an average value of the frequency components of the position correction signal, and the above-described configuration allows existence of overlapping portion between a frequency distribution of the vibration suppression signal and a frequency distribution of the position correction signal.

[0029] By configuring the operation amount calculation unit 8 in the above-described manner, the operation amount calculation unit 8 separates the component used for suppressing vibration and the component used for correcting position from the measured value of displacement of a metal strip by the non-contact displacement sensor 4, and transmits the vibration suppression signal and the position correction signal to the vibration suppression obverse/reverse distribution unit 9a and the position correction obverse/reverse distribution unit 9b, respectively.

[0030] The explanation returns to reference to FIG. 3. The obverse/reverse distribution units 9a and 9b distributes the vibration suppression signal and the position correction signal calculated by the operation amount calculation unit 8 to the electromagnet 3a for use on an obverse surface and the electromagnet 3b for use on a reverse surface of the metal strip 2. The amplifier 10a supplies power to the vibration suppression coil of the electromagnet 3a in accordance with the vibration suppression signal distributed by the obverse/reverse distribution unit 9a for use on the obverse surface, and the amplifier 10b supplies power to the position correction coil of the electromagnet 3a in accordance with the position correction signal distributed by the obverse/reverse distribution unit 9b for use at the obverse surface. On the other hand, the amplifier 10c supplies power to the vibration suppression coil of the electromagnet 3b in accordance with the vibration suppression signal distributed by the obverse/reverse distribution unit 9a for use on the reverse surface, and the amplifier 10d supplies power to the position correction coil of the electromagnet 3b in accordance with the position correction signal distributed by the obverse/reverse distribution unit 9b for use on the reverse surface.

[0031] FIG. 5 is a schematic view showing an electric circuit of the electromagnet 3a in the metal strip stabilizer 1 according to the embodiment of the present invention. Herein, due to limitations of a space, only an electric circuit corresponding to the electromagnet 3a for use on the obverse surface of the metal strip 2 is schematically shown.

[0032] As shown in FIG. 5, the vibration suppression amplifier 10a and the position correction amplifier 10b are connected to the vibration suppression coil 7a and the position correction coil 7b, respectively. The vibration suppression amplifier 10a supplies power to the vibration suppression coil 7a via an electric circuit in accordance with the input vibration suppression signal. The position correction amplifier 10b supplies power to the position correction coil 7b via an electric circuit in accordance with the input position correction signal.

[0033] Furthermore, an electric circuit including the position correction coil 7b and the position correction amplifier 10b includes coils 13a in series as an inductor 11a. Hereinafter, this is called the counter induced current coil 13a. In an example of the counter induced current coil 13a shown in FIG. 5, an example of a coil in which the magnetic circuit 13b

is configured by a closed circuit is shown. It should be noted that the coil in which the magnetic circuit 13b is configured by the closed circuit is called a toroidal coil. Although the magnetic circuit 13b of the counter induced current coil 13a can obtain the effect even if it is configured by an open circuit, it is preferable to configure the magnetic circuit 13b of the counter induced current coil 13a by the closed circuit for not being affected by an environmental change by leak, etc. of magnetic flux.

[0034] The counter induced current coil 13a configured in the above-described manner operates as follows in the metal strip stabilizer 1 according to the embodiment of the present invention.

[0035] High frequency current is supposed to flow in the vibration suppression coil 7a in accordance with the vibration frequency of the metal strip 2. Then, since the vibration suppression coil 7a and the position correction coil 7b are configured as concentric coils, a high frequency electromotive force is generated in the position correction coil 7b by a mutual induction.

[0036] In a conventional metal strip stabilizer, the electric current in the position correction coil 7b fluctuated by the electromotive force of the mutual induction, thereby the attraction force of the position correction coil 7b fluctuated, and a bad influence was exerted to the vibration control. However, in the metal strip stabilizer 1 according to the embodiment of the present invention, since the counter induced current coil 13a is connected to the electric circuit of the position correction coil 7b, a change in the electric current in the electric circuit of the position correction coil 7b can be suppressed by the inductance of the counter induced current coil 13a. Hereinafter, a mechanism of suppressing fluctuation in the electric current in the electric circuit of the position correction coil 7b by the counter induced current coil 13a will be explained.

[0037] When the electric current flowing in the vibration suppression coil 7a is i_1 and the electric current flowing in the position correction coil 7b is i_2 , the induced electromotive force e_1 generated in the vibration suppression coil 7a and the induced electromotive force e_2 generated in the position correction coil 7b are represented by the following equations.

$$e_1 = -M di_2/dt \quad (4)$$

$$e_2 = -M di_1/dt \quad (5)$$

where M is mutual inductance between the vibration suppression coil 7a and the position correction coil 7b and is represented by the following equation.

$$M = k \times \sqrt{(L_1 \times L_2)} \quad (6)$$

where k is a coefficient determined in accordance with a shape or a mutual position of the coils, L_1 is the inductance of the vibration suppression coil 7a, and L_2 is the inductance of the position correction coil 7b.

[0038] A static current for conducting the position correction is supposed to flow in the position correction coil 7b, and a temporal change di_2/dt in the electric current becomes substantially zero. Therefore, as understood from the above-described equation (4), the very little induced electromotive force e_1 is generated in the vibration suppression coil 7a. That is, the position correction current flowing in the position correction coil 7b exerts a very little influence to the vibration suppression control by the vibration suppression coil 7a.

[0039] On the other hand, a dynamic current for suppressing vibration is supposed to flow in the vibration suppression coil 7a, and so a temporal change di_1/dt in the current is large. Therefore, as understood from the above-described equation (5), the large induced electromotive force e_2 is generated in the position correction coil 7b.

[0040] However, in the metal strip stabilizer 1 according to the embodiment of the present invention, since the counter induced current coil 13a is connected to the electric circuit of the position correction coil 7b, the current generated by the induced electromotive force is suppressed by a combined inductance of the position correction coil 7b and the counter induced current coil 13a.

[0041] As explained with reference to FIG. 5, since the position correction coil 7b and the counter induced current coil 13a are connected in series, the combined inductance L of the position correction coil 7b and the counter induced current coil 13a is represented by the following equation.

$$L = L_2 + L_3 \quad (7)$$

where L_2 and L_3 are the inductances of the position correction coil 7b and the counter induced current coil 13a, respectively.

[0042] By the way, reactance of alternating current flowing in a coil is in proportion with a frequency of the alternating current and an inductance. On the other hand, as described above, the vibration suppression signal is a signal including a lot of the high frequency components, and the position correction signal is a signal including a lot of the low frequency components. Therefore, the electric current induced from the vibration suppression coil 7a to the position correction coil 7b is an electric current including a lot of the high frequency components and is affected to a significant degree by a magnitude of the combined inductance L , and thus suppressed. On the other hand, the electric current flowing in the position correction coil 7b is not affected to a significant degree by the magnitude of the combined inductance L . In addition, as understood from the equation (7), since the magnitude of the inductance L_2 of the position correction coil 7b does not change even if the counter induced current coil 13a is connected and the combined inductance L becomes large, characteristics of an electromagnet by the position correction coil 7b do not change.

[0043] As described above, the movement of the electromagnet is in the primary delay system, and its time constant is given by the equation (2). Therefore, the larger the combined inductance L is, the larger the time constant is, and thus, it is possible to suppress the fluctuation in the electric current. On the other hand, although the combined inductance L can be increased by increasing the winding number of the counter induced current coil 13a, there are disadvantages in case where the winding number is larger, that a load to an amplifier becomes larger as resistance of an entire circuit becomes larger and more space is necessary for disposing as the counter induced current coil 13a becomes larger in size..

[0044] Then, it is necessary to determine the inductance of the counter induced current coil in consideration of the vibration-controlling performance and the above-described disadvantage. Based on the later-described demonstration experiment for the effect according to the embodiment of the present invention, it is preferable to set a serially-combined time constant for the position correction coil 7b and the counter induced current coil 13a within a range of four to ten times of the position correction coil 7b. In another expression of this condition based on the relation of the equation (2), it is preferable to design the metal strip stabilizer 1 according to the embodiment of the present invention so that the vibration suppression coil 7a, the position correction coil 7b, and the counter current coil 13a satisfy the range of the following equation.

$$4L_2/R_2 < (L_2+L_3)/(R_2+R_3) < 10L_2/R_2 \quad (8)$$

where L_2 and L_3 are the inductances of the position correction coil 7b and the counter induced current coil 13a, respectively, and R_2 and R_3 are resistances of the position correction coil 7b and the counter induced current coil 13a, respectively.

[0045] It should be noted that, disposing the counter induced current coil 13a worsens the responsiveness of the position correction coil 7b intentionally. However, as described above, since the responsiveness is not required for the position correction coil 7b, it is not affected to the position correction for the metal strip. As a result, it is possible to suppress the mutual induced current by the vibration suppression coil 7a and the position correction coil 7b, to avoid a bad influence to the vibration control, and to make the responsiveness of the vibration suppression coil 7a consistent with the attraction force of the position correction coil 7b.

[0046] Next, an example of a configuration is explained in which the metal strip stabilizer 1 according to the embodiment of the present invention is disposed in a manufacturing line for a hot-dip coated metal strip.

[0047] FIG. 6 is a schematic view showing a part of a commonly used manufacturing line for a hot-dip coated metal strip. In the manufacturing line for the hot-dip coated metal strip shown in FIG. 6, the metal strip 2 is transferred from a previous step such as a cold-rolling process, undergoes annealing treatment in an annealing furnace 14 of which inside is maintained at non-oxidizing or reducing atmosphere, thereafter undergoes cooling treatment to a level similar to the temperature of molten metal, and is introduced into a hot-dip metal bath 15.

[0048] In the hot-dip metal bath 15, the metal strip 2 is immersed and passes through the molten metal, and the molten metal adheres on a surface of the metal strip 2. After that, excessive molten metal of the metal strip 2 pulled out from the hot-dip metal bath 15 is shaken off by a gas discharged from a gas wiper 16 to adjust the adhering amount of the molten metal.

[0049] In a subsequent process, there is a case where the metal strip is reheated by using an alloying furnace 17 to conduct an alloying treatment for making a uniform alloy layer depending on usage, for example, in case where the metal strip 2 is used as an outer panel of an automobile. After passing through a cooling zone 18, the metal strip 2 undergoes a special rust-inhibiting and corrosion-resistant treatment by a chemical processing unit 19 and is wound in a coil, and then shipped.

[0050] FIG. 7 is an enlarged view showing the vicinity (an area indicated by a dotted line in FIG. 6) of the gas wiper of the manufacturing line for the hot-dip coated metal strip. As shown in FIG. 7, in the vicinity of the gas wiper 16 of the manufacturing line for a hot-dip coated metal strip, a drawing roller 20 draws the metal strip 2 into the hot-dip metal bath 15 to make molten metal adhered to the metal strip 2 in the hot-dip metal bath 15, and a pull-up roller 21 pulls up the metal strip 2 to outside the hot-dip metal bath 15. The gas wiper 16 is disposed in the middle of a pass line of the pull-up roller 21 pulling up the metal strip 2 and adjusts the adhering amount of the molten metal by shaking off the excessive molten metal adhered to the metal strip 2.

[0051] The electromagnets 3a and 3b and the non-contact displacement sensor 4 of the metal strip stabilizer 1 according to the embodiment of the present invention are disposed at the pass line immediately above the gas wiper 16 to control vibration and position of the metal strip. By this disposition, as a result that distance between the gas wiper 16 and the metal strip 2 becomes constant, pressure by the wiping gas becomes uniform, and unevenness in the amount of the molten metal adhering to the metal strip 2 can be suppressed.

[0052] Finally, a verification experiment for the effect of the metal strip stabilizer 1 according to the embodiment of the present invention will be explained. FIG. 8 is a graph showing data measured by a metal strip stabilizer according to a comparative example, and FIG. 9 is a graph showing data measured by the metal strip stabilizer 1 according to the embodiment of the present invention. In addition, FIG. 10 is a graph in which magnitudes of noise included in the measured data shown in FIG. 8 and the measured data shown in FIG. 9 are compared.

[0053] The graph shown in FIG. 8 plots actual values of an electric current in a metal strip stabilizer without the counter induced current coil 13a when a vibration control command at an electric current of 3A at a frequency of 10 Hz is given to the vibration suppression coil 7a, and a control command at a constant current of 0A is given to the position correction coil 7b. It should be noted that, in the graph shown in FIG. 8, the values of the electric current of the vibration control command is described together.

[0054] As understood from the graph shown in FIG. 8, in the comparative example, although the constant current of 0A is supposed to flow in the position correction coil 7b, a current is detected as an actual value. This current flowing in the position correction coil 7b is an induced current which is generated at the position correction coil 7b side by electromagnetic induction due to the fluctuation in the current for the vibration control flowing in the vibration suppression coil 7a. Furthermore, according to the graph shown in FIG. 8, by the fluctuation in the induced current flowing in the position correction coil 7b, an induced current also flows at the vibration suppression coil 7a side and disturbance is generated in the actual current for the vibration control.

[0055] The graph shown in FIG. 9 plots actual values of an electric current in the metal strip stabilizer 1 according to the embodiment of the present invention when a vibration control command at an electric current of 3A at a frequency of 10 Hz is given to the vibration suppression coil 7a, and a control command at a constant current of 0A is given to the position correction coil 7b. It should be noted that the inductance of the counter induced current coil 13a in this verification experiment is designed so that the serially-combined time constant of the position correction coil 7b and the counter induced current coil 13a is five times of the position correction coil 7b.

[0056] As understood from the graph shown in FIG. 9, influence by the induced current is very little in the vibration suppression coil 7a and the position correction coil 7b according to the embodiment of the present invention, and the control precisely following the control commands is realized. In addition, as understood from a comparison of the graphs shown in FIGS. 8 and 9, although, in the vibration suppression coil 7a and the position correction coil 7b in the comparative example, a vicious circle occurs in which the fluctuation in the induced current induced to the position correction coil 7b further affects the vibration suppression coil 7a, this vicious cycle does not occur in the vibration suppression coil 7a and the position correction coil 7b according to the embodiment of the present invention. Moreover, as understood from the graph shown in FIG. 10, according to the metal strip stabilizer 1 according to the embodiment of the present invention, it is possible to reduce the induced current which disturbs the vibration control to one-eleventh. That is, the metal strip stabilizer 1 according to the embodiment of the present invention can avoid lowering of the vibration-controlling performance due to the induced current between the vibration suppression coil and the position correction coil.

[0057] As above described, since the metal strip stabilizer 1 according to the embodiment of the present invention includes the non-contact displacement sensor 4 that measures displacement of the metal strip 2 during online running, the control unit 5 that outputs the vibration suppression signal for suppressing vibration of the metal strip 2 and the position correction signal for correcting a position of the metal strip 2 after a signal is input from the non-contact displacement sensor 4, the vibration suppression coil 7a that generates a magnetic force in accordance with the vibration suppression signal output from the control unit 5, the position correction coil 7b that generates a magnetic force in accordance with the position correction signal output from the control unit 5, the winding number of the second coil being larger than a winding number of the vibration suppression coil 7a, the core 6 around which the vibration suppression coil 7a and the position correction coil 7b are wound concentrically and that induces the magnetic force generated by the vibration suppression coil 7a and the position correction coil 7b to the metal strip 2, and the counter induced current coil 13a that is disposed in series to the electric circuit supplying electricity to the position correction coil 7b; therefore, loss in the vibration suppression performance caused by the induced current between the vibration suppression coil 7a

and the position correction coil 7b may be prevented.

[0058] Here, the control unit 5 of the metal strip stabilizer 1 according to the embodiment of the present invention outputs the vibration suppression signal by performing calculation to a difference signal between the signal input from the non-contact displacement sensor 4 and a target value such that the gain of the high frequency component becomes larger than the position correction signal, and outputs the position correction signal by performing calculation such that the gain of the low frequency component becomes larger than the vibration suppression signal; therefore, it is possible to allot an appropriate signal for the vibration control and an appropriate signal for the position correction from the measured displacement amount. Moreover, it is preferable that the control unit 5 of the metal strip stabilizer 1 according to the embodiment of the present invention outputs the vibration suppression signal by performing the PID control calculation, in which the derivative gain is set to be larger than the position correction signal, to the difference signal between the signal input from the non-contact displacement sensor 4 and a target value, and outputs the position correction signal by performing the PID control calculation, in which the integral gain is set to be larger than the vibration suppression signal.

[0059] Moreover, it is preferable that the serially-combined time constant of the position correction coil 7b and the counter induced current coil 13a of the metal strip stabilizer 1 according to the embodiment of the present invention is designed to be within a range of four to ten times of the time constant of the position correction coil 7b. Alternatively, it is preferable that the position correction coil 7b and the counter induced current coil 13a of the metal strip stabilizer 1 according to the embodiment of the present invention satisfy the below-described equation:

$$4L_2/R_2 < (L_2+L_3)/(R_2+R_3) < 10L_2/R_2$$

where L_2 and L_3 are the inductances of the position correction coil 7b and the counter induced current coil 13a, respectively, and R_2 and R_3 are the resistances of the position correction coil 7b and the counter induced current coil 13a, respectively.

[0060] Moreover, since the metal strip stabilizer 1 according to the embodiment of the present invention disposes the vibration suppression coils 7a, the position correction coils 7b and the cores 6 on the obverse and the reverse surfaces of the metal strip 2, wherein the vibration suppression coil 7a, the position correction coil 7b and the core 6 for the obverse surface are disposed on the obverse surface, and the vibration suppression coil 7a, the position correction coil 7b and the core 6 for the reverse surface are disposed on the reverse surface; therefore, vibration to and displacement of the obverse and the reverse surfaces of the metal strip 2 can be suppressed.

[0061] Since the control unit 5 of the metal strip stabilizer 1 according to the embodiment of the present invention includes the operation amount calculation unit 8 that outputs the vibration suppression signal suppressing vibration of the metal strip 2 and the position correction signal for correcting the position of the metal strip 2 after a signal is input from the non-contact displacement sensor 4, the obverse/reverse distribution unit 9a that distributes the vibration suppression signal output from the operation amount calculation unit 8 to the vibration suppression coil 7a for the obverse surface and the vibration suppression coil 7a for the reverse surface, the obverse/reverse distribution unit 9b that distributes the position correction signal output from the operation amount calculation unit 8 to the position correction coil 7b for the obverse surface and the position correction coil 7b for the reverse surface, the amplifier 10a that supplies power to the vibration suppression coil 7a for the obverse surface in accordance with the vibration suppression signal for the obverse surface distributed by the obverse/reverse distribution unit 9a, the amplifier 10b that supplies power to the position correction coil 7b for the obverse surface in accordance with the position correction signal for the obverse surface distributed by the obverse/reverse distribution unit 9b, the amplifier 10c that supplies power to the vibration suppression coil 7a for the reverse surface in accordance with the vibration suppression signal for the reverse surface distributed by the obverse/reverse distribution unit 9a, and the amplifier 10d that supplies power to the position correction coil 7b for the reverse surface in accordance with the position correction signal for the reverse surface distributed by the obverse/reverse distribution unit 9b, and the counter induced current coils 13a are disposed at electric circuits between the amplifier 10b and the position correction coil 7b for the obverse surface and between the amplifier 10d and the position correction coil 7b for the reverse surface, respectively; therefore, both vibration to and displacement of the obverse and the reverse surfaces of the metal strip 2 can be suppressed.

[0062] Moreover, since a magnetic circuit 13b of the counter induced current coil 13a is configured as a closed circuit, the metal strip stabilizer 1 according to the embodiment of the present invention is hardly affected by an environmental change due to leak, etc. of magnetic flux.

[0063] Furthermore, a method of manufacturing a hot-dip coated metal strip according to the embodiment of the present invention includes the steps of adhering molten metal to the metal strip 2 passing through the manufacturing line, adjusting the adhering amount of the molten metal by the gas wiper 16 shaking off the excessive molten metal adhering to the metal strip 2, and controlling vibration and a position of the metal strip 2 in a non-contact manner by the above-described metal strip stabilizer 1; therefore, unevenness in the amount of the molten metal adhered to the metal

strip 2 can be suppressed.

[0064] Moreover, since the metal strip according to the embodiment of the present invention is manufactured by the above-described manufacturing method, unevenness in the adhering amount of the molten metal can be suppressed.

[0065] As described above, although the present invention is explained based on the embodiment, when carrying out the present invention, the present invention is not limited by the wordings and the drawings constituting a part of the disclosure of the present invention by the present embodiment.

Industrial Applicability

[0066] The present invention is useful for a manufacturing line for a metal strip, and in particular, a manufacturing line for a hot-dip coated metal strip.

Reference Signs List

[0067]

1	metal strip stabilizer
2	metal strip
3a, 3b	electromagnet
4	non-contact displacement sensor
5	control unit
6	core
7a	vibration suppression coil
7b	position correction coil
8	operation amount calculation unit
9a, 9b	obverse/reverse distribution unit
10a to 10d	amplifier
11a, 11b	inductor
12	input unit
13a	counter induced current coil
13b	magnetic circuit
14	annealing furnace
15	hot-dip metal bath
16	gas wiper
17	alloying furnace
18	cooling zone
19	chemical processing unit
20	drawing roller
21	pull-up roller

Claims

1. A metal strip stabilizer comprising:

a non-contact displacement sensor that measures displacement of a metal strip during online running;
 a control unit that outputs a vibration suppression signal for suppressing vibration of the metal strip and a position correction signal for correcting a position of the metal strip after a signal is input from the non-contact displacement sensor;
 a first coil that generates a magnetic force in accordance with the vibration suppression signal output from the control unit;
 a second coil that generates a magnetic force in accordance with the position correction signal output from the control unit, a winding number of the second coil being larger than a winding number of the first coil;
 a core around which the first coil and the second coil are wound concentrically and that induces the magnetic force generated by the first coil and the second coil to the metal strip; and
 a third coil that is disposed in series to an electric circuit supplying electricity to the second coil.

2. The metal strip stabilizer according to claim 1, wherein the control unit outputs the vibration suppression signal by

performing calculation to a difference signal between the signal input from the non-contact displacement sensor and a target value such that a gain of a high frequency component becomes larger than the position correction signal, and outputs the position correction signal by performing calculation such that a gain of a low frequency component becomes larger than the vibration suppression signal.

3. The metal strip stabilizer according to claim 1 or 2, wherein the control unit outputs the vibration suppression signal by performing a PID control calculation, in which derivative gain is set to be larger than the position correction signal, to a difference signal between the signal input from the non-contact displacement sensor and a target value, and outputs the position correction signal by performing a PID control calculation, in which integral gain is set to be larger than the vibration suppression signal.
4. The metal strip stabilizer according to any one of claims 1 to 3, wherein a serially-combined time constant of the second coil and the third coil is designed to be within a range of four to ten times of a time constant of the second coil.
5. The metal strip stabilizer according to any one of claims 1 to 4, wherein the second coil and the third coil satisfy an equation:

$$4L_2/R_2 < (L_2+L_3)/(R_2+R_3) < 10L_2/R_2$$

where L_2 and L_3 are inductances of the second coil and the third coil, respectively, and R_2 and R_3 are resistances of the second coil and the third coil, respectively.

6. The metal strip stabilizer according to any one of claims 1 to 5, wherein a magnetic circuit of the third coil is configured as a closed circuit.
7. A method of manufacturing a hot-dip coated metal strip, the method comprising the steps of:
 - adhering molten metal to a metal strip passing through a manufacturing line;
 - adjusting a adhering amount of the molten metal by a gas wiper shaking off excessive molten metal adhering to the metal strip; and
 - controlling vibration and a position of the metal strip in a non-contact manner by the metal strip stabilizer of any one of claims 1 to 6.
8. A metal strip manufactured by the method according to claim 7.

FIG.1

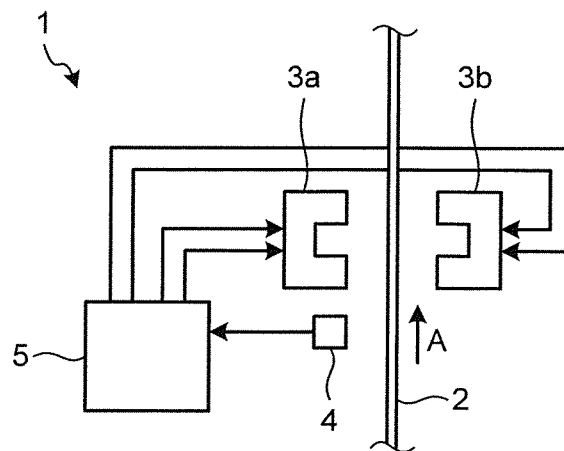


FIG.2

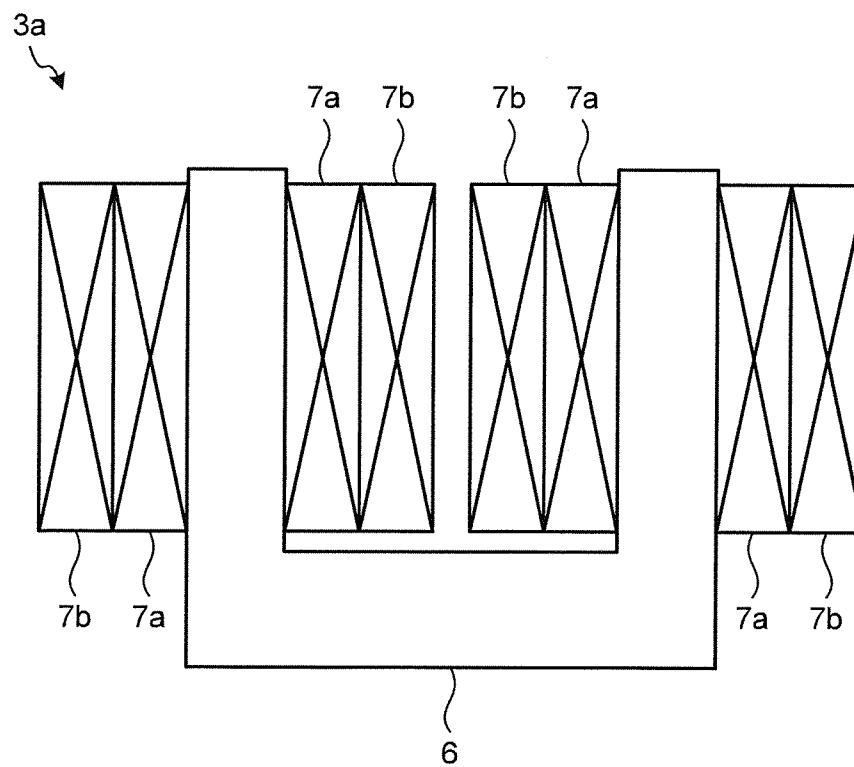


FIG.3

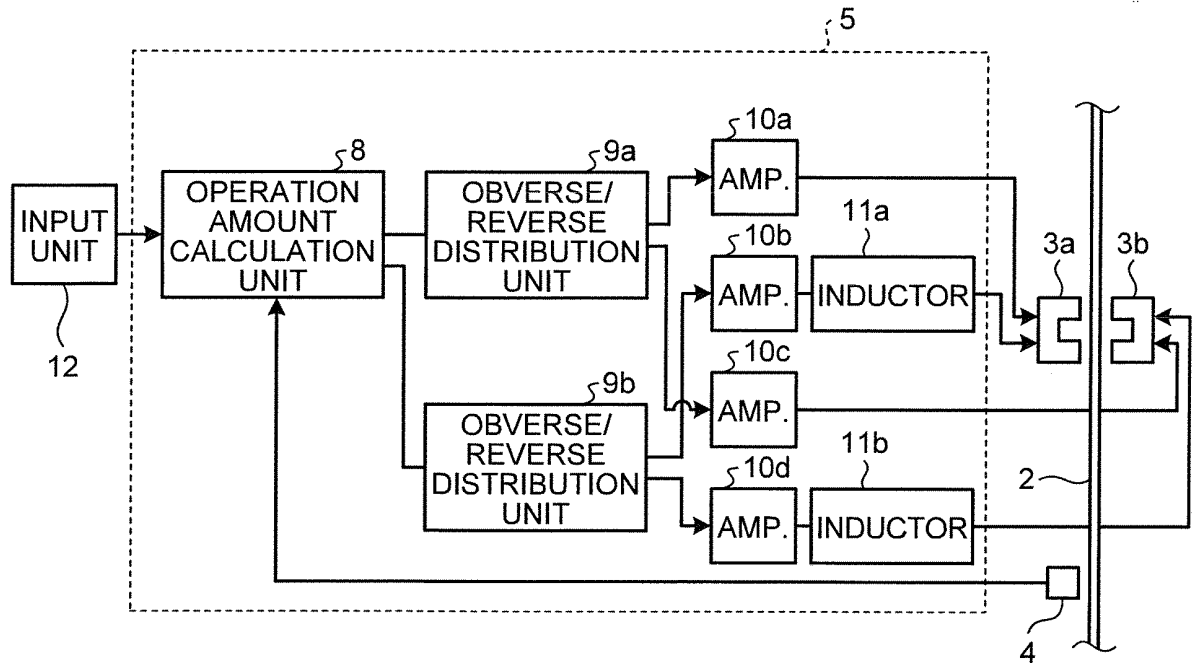


FIG.4

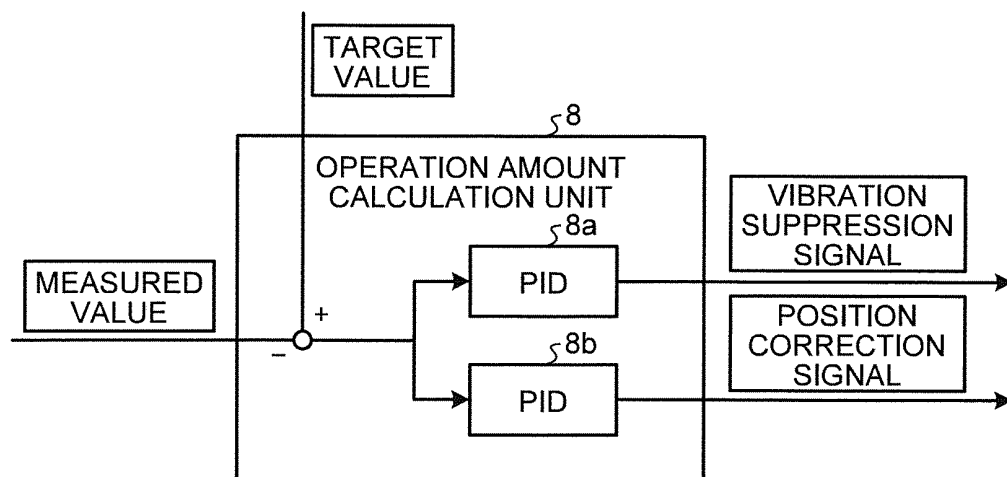


FIG.5

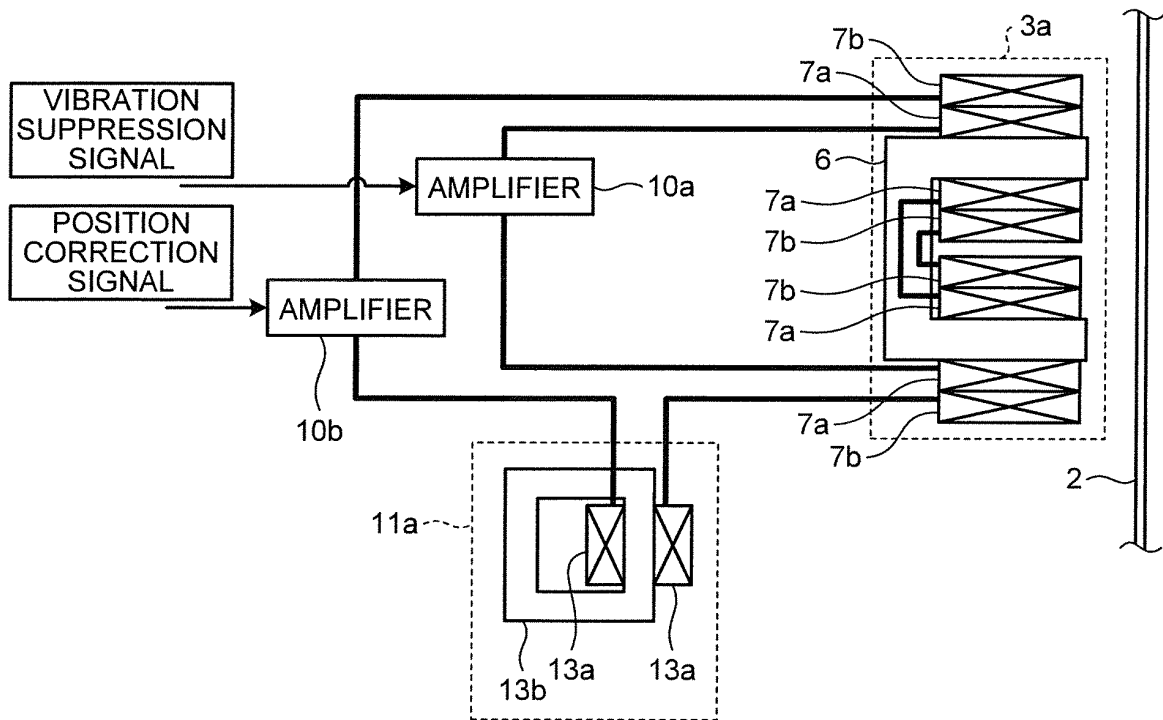


FIG.6

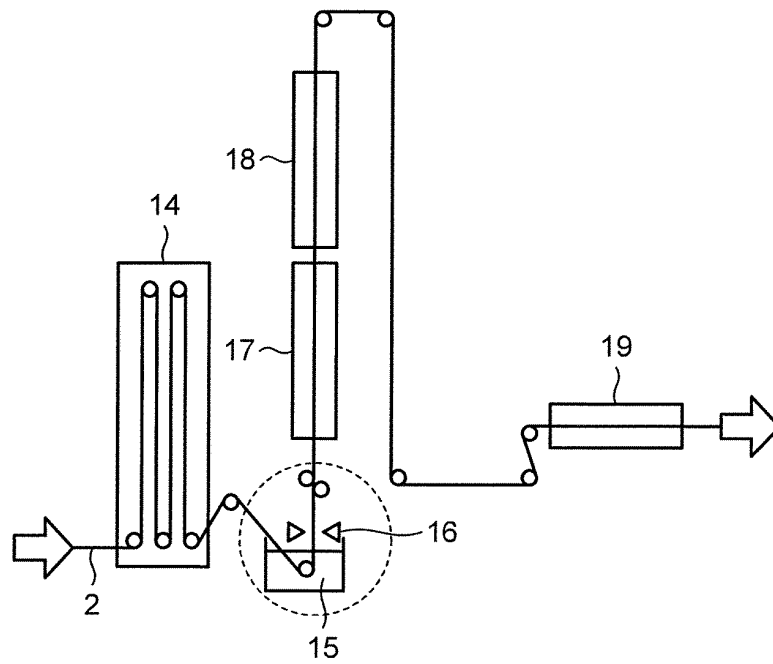


FIG.7

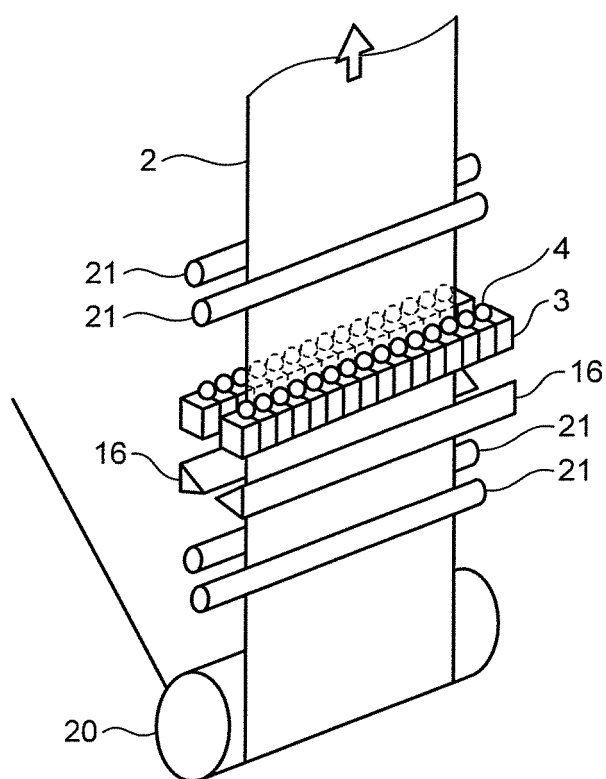


FIG.8

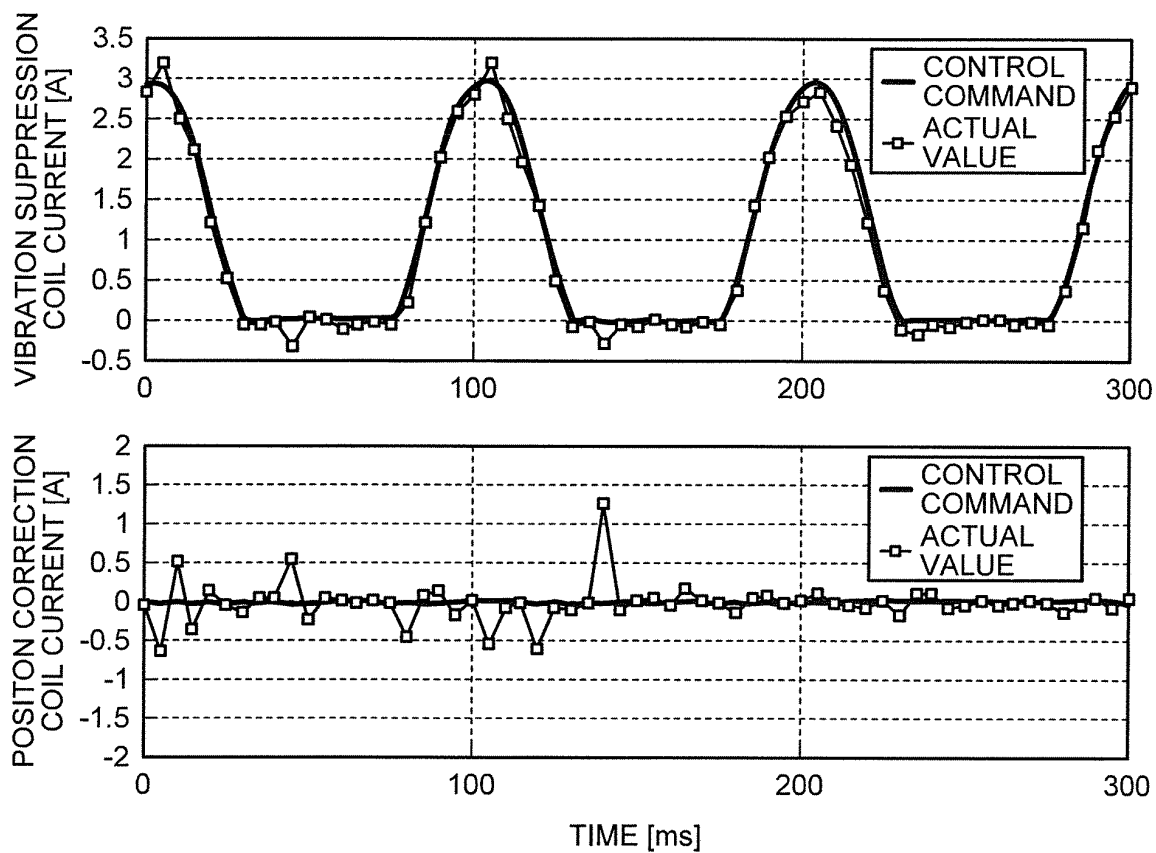


FIG.9

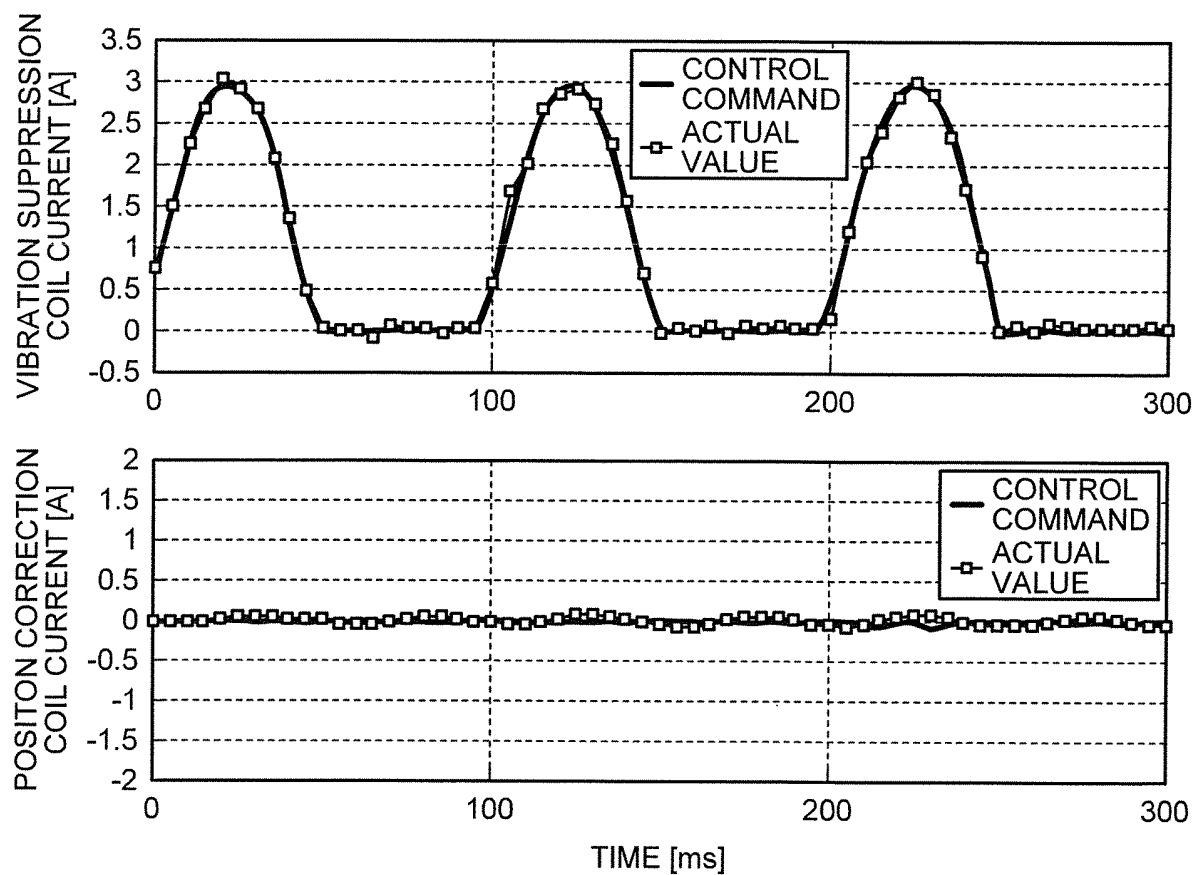
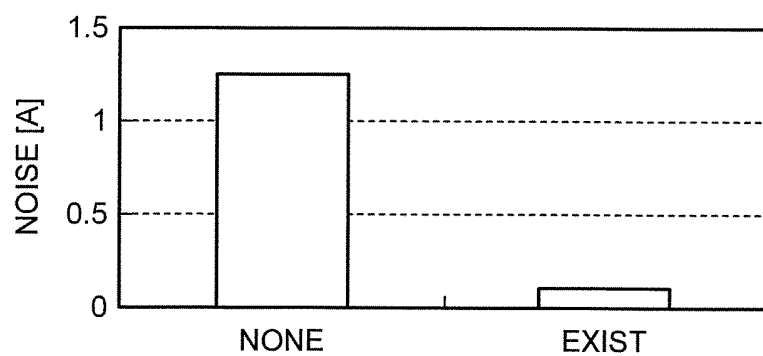


FIG.10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/070115

A. CLASSIFICATION OF SUBJECT MATTER

C23C2/40(2006.01)i, B65H23/04(2006.01)i, F16F15/02(2006.01)i

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)

C23C2/40, B65H23/04, F16F15/02

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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.
X A	JP 2004-124191 A (JFE Steel Corp.), 22 April 2004 (22.04.2004), claims; paragraphs [0020], [0043] to [0044], [0062], [0063]; fig. 4, 9 (Family: none)	8 1-7
A	WO 2001/071051 A1 (SMS DEMAG AG), 27 September 2001 (27.09.2001), pages 8 to 10; fig. 1 to 5 & DE 10014867 A & AU 5472801 A & EG 22837 A	1-8
A	JP 2009-141255 A (Kobe Steel, Ltd.), 25 June 2009 (25.06.2009), claims; paragraphs [0006] to [0009]; fig. 1 to 5 (Family: none)	1-8

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

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Date of the actual completion of the international search

05 November, 2012 (05.11.12)

Date of mailing of the international search report

13 November, 2012 (13.11.12)

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- JP 2062355 A [0008]
- JP 2004124191 A [0008]