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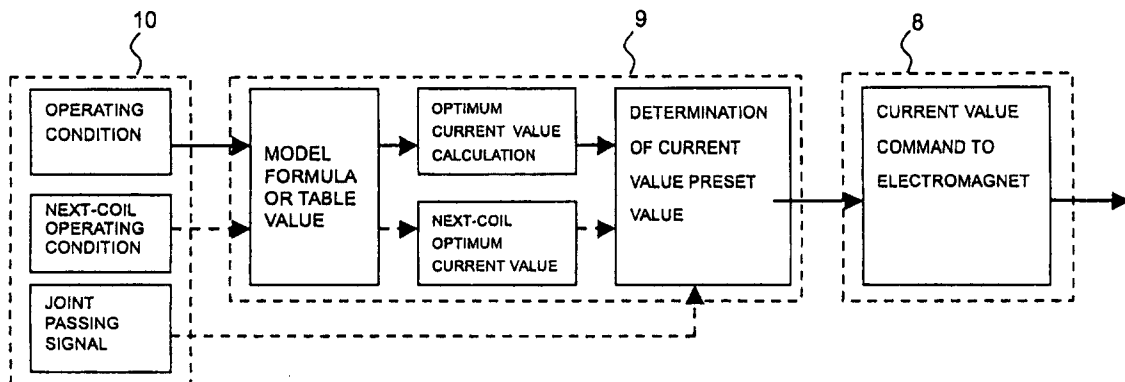
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(54) **MOLTEN METAL PLATED STEEL SHEET PRODUCTION METHOD AND APPARATUS**

(57) The invention provides a method for producing hot-dip metal coated steel sheet, comprising the steps of: continuously immersing a steel sheet in a hot-dip metal coating bath to adhere the molten metal of the bath onto a surface of the steel sheet; changing the running direction of the steel sheet using a direction-changing device located in the hot-dip metal coating bath, and then drawing up thereof from the bath; adjusting the coating weight of the molten metal adhered to the steel sheet using a gas-wiping device; and correcting the warp appeared on the steel sheet in non-contact state

by the magnetic force using electromagnets which are positioned at upstream side and/or downstream side of the gas-wiping device and which apply the magnetic force to the steel sheet in the direction crossing the surface thereof. The current value of the electromagnet is set to a current value preliminarily determined on the basis of information relating to the steel sheet. The method allows producing a hot-dip metal coated steel sheet which suppresses the generation of warp over the whole length of the steel sheet, gives uniform coating weight, and provides excellent surface property.

**FIG. 6**



**Description****FIELD OF THE INVENTION**

5 [0001] The present invention relates to a method for producing a hot-dip metal coated steel sheet, specifically to a method of shape correction on the steel sheet using an electromagnet in non-contact state, and to an apparatus for producing thereof.

**DESCRIPTION OF THE RELATED ARTS**

10 [0002] Hot-dip metal coating represented by hot-dip galvanizing has long been practically applied. In particular the hot-dip galvanized steel sheets have shown increasing demand as the plated corrosion proof steel sheets for automobiles, household electric appliances, and building materials, and face the requirement of higher quality including uniform coating weight and suppression of surface defects than ever.

15 [0003] As for the method to coat a molten metal onto a continuous steel sheet, or for example the method for producing hot-dip galvanized steel sheet, gas-wiping method is currently adopted using an apparatus shown in Fig. 1 as an example. According to the method, a steel sheet S which is continuously immersed in a hot-dip metal coating bath 2 is drawn up vertically from the bath, and the excessive amount of molten metal adhered to the steel sheet S is removed by high pressure gas ejected from a gas-wiping device 4 positioned against each side of the steel sheet S, thus adjusting the desired coating weight.

20 [0004] With the apparatus shown in Fig. 1, however, the steel sheet drawn up from the coating bath vibrates or generates warp in width direction thereof. Furthermore, in some cases, degraded flatness of the steel sheet occurs. If those defects occurred, the distance between the gas-wiping device and the steel sheet varies, which results in non-uniform coating weight in the longitudinal direction or the width direction of the steel sheet. To this point, there is a commonly applied countermeasure in which a pair of support rolls is installed in the bath, and further a pair of similar support rolls is located above the gas-wiping device to restrict the steel sheet, thus preventing the vibration of the steel sheet and conducting the correction of warp thereon. That type of support-roll method, however, may fail to attain satisfactory effect of prevention of vibration and shape correction in some cases.

25 [0005] Responding to the problem, there is a proposal of method to suppress the vibration of steel sheet utilizing magnetic force applying electromagnets. For example, Japanese Patent Laid-Open No. 2001-38412 discloses a damping device for damping the running steel sheet. That is, a pair of electromagnets to apply magnetic force against the steel sheet and a position sensor are mounted, thus the driving current for the electromagnet pair is controlled on the basis of the determined distance between the electromagnet and the steel sheet, and the control gain in the current control is determined on the basis of information relating to the steel sheet, such as the information of thickness, running speed, joint position, width, and tension of the steel sheet.

30 [0006] The damping device and the damping method using electromagnets in the related art, however, raise the problems described below.

35 [0007] Regarding the method using electromagnets, a position sensor for determining the position of steel sheet (distance from the electromagnet) is required to prevent contact of electromagnet with the steel sheet and to prevent attracting and catching the steel sheet by the electromagnet. Consequently, the method not only increases the cost but also increases the apparatus size to disturb the gas stream of the gas-wiping device, which makes the installation of electromagnets near the gas-wiping device difficult.

40 [0008] As for the method using electromagnets in the related art, the feedback control is conducted on the basis of position information supplied from the position sensor. Thus, after generated vibration and warp on the steel sheet, the phenomenon is recognized by the position sensor, and then the current value of electromagnet is changed. At joint between forerunning steel sheet and succeeding steel sheet, however, the condition of warp may suddenly vary. In that case, the feedback control cannot respond to the sudden change of warp condition so that the warp at the front section of succeeding steel sheet cannot be corrected.

45 [0009] Furthermore, since the warp may not be corrected locally, as described above, the distance between the gas-wiping device and the steel sheet has to be widened to minimize the contact therebetween even if a warp occurred. With a wide distance between the gas-wiping device and the steel sheet, however, the gas-wiping is requested to be done with higher gas pressure and larger gas flow rate, which makes the adjustment to a desired coating weight difficult. In addition, a defect (splash defect) likely occurs. The splash defect is a phenomenon of adhering molten metal splash to the steel sheet caused by the gas stream near the gas-wiping device.

50 [0010] As described above, the method using electromagnets of the related art has problems of cost increase, insufficient effect of warp correction, and failing in producing high quality coated steel sheet.

**SUMMARY OF THE INVENTION**

**[0011]** It is an object of the present invention to provide a method for producing a hot-dip metal coated steel sheet which suppresses generation of warp over the whole length thereof, gives uniform coating weight, and has excellent surface property, and to provide an apparatus therefor.

**[0012]** The object is attained by a method for producing a hot-dip metal coated steel sheet, comprising the steps of: continuously introducing a steel sheet in a hot-dip metal coating bath of a molten metal to adhere the molten metal onto a surface of the steel sheet; changing a running direction of the steel sheet using a direction-changing device located in the hot-dip metal coating bath, and then taking the steel sheet out from the bath; adjusting a coating weight of the molten metal adhered to the steel sheet using a gas-wiping device; correcting a warp appeared on the steel sheet in non-contact state by magnetic force using an electromagnet positioned at upstream side and/or downstream side of the gas-wiping device, the electromagnet applying the magnetic force to the steel sheet in the direction crossing the surface thereof; and setting a current value of electromagnet to a predetermined current value on the basis of information relating to the steel sheet.

**[0013]** The method is realized by an apparatus for producing a hot-dip metal coated steel sheet, comprising: a hot-dip metal coating bath tank for adhering a molten metal onto a surface of a steel sheet; a direction-changing device located in the hot-dip metal coating bath tank to change a running direction of the steel sheet; a gas-wiping device positioned above the surface of the coating bath of the hot-dip metal coating bath tank to adjust the coating weight of the molten metal adhered to the steel sheet; an electromagnet positioned at upstream side and/or downstream side of the gas-wiping device to apply magnetic force to the steel sheet in the direction crossing the surface thereof to correct a warp appeared on the steel sheet in non-contact state; and a current value preset control device to set the current value of electromagnet to a current value preliminarily determined on the basis of information relating to the steel sheet.

**BRIEF DESCRIPTION OF THE DRAWINGS****[0014]**

Fig. 1 shows an apparatus for producing hot-dip galvanized steel sheet according to the related art.

Fig. 2 is a conceptual drawing explaining the displacement of steel sheet and the force applied to the steel sheet on correcting warp of the steel sheet.

Fig. 3 shows a relation between the displacement of steel sheet and the force applied to the steel sheet.

Fig. 4 shows an apparatus for producing hot-dip metal coated steel sheet according to the present invention.

Fig. 5 shows an arrangement of electromagnets in the width direction of steel sheet according to the present invention.

Fig. 6 shows a preset control flow diagram according to the present invention.

Fig. 7 shows another apparatus for producing hot-dip metal coated steel sheet according to the present invention.

Fig. 8 shows a feedback control flow diagram according to the present invention.

Fig. 9 compares the shape controllability between the present invention and the related art.

**DESCRIPTION OF THE EMBODIMENTS**

**[0015]** In the related art that suppresses vibration and warp of steel sheet using electromagnets, it is thought that "feedback control" is indispensable to conduct the control of current applied to the electromagnet, as described above.

The magnetic force of electromagnet is inversely proportional to the square of distance between the electromagnet and the steel sheet. When the steel sheet is attracted toward the electromagnet caused by the magnetic force, the magnetic force applied to the steel sheet increases, thus the steel sheet is further attracted toward the electromagnet to touch to or being caught by the electromagnet to induce facility troubles. The feedback control prevent the facility troubles. The attraction of steel sheet by the electromagnet is, therefore, an "instable system".

Consequently, it is accepted that the feedback control using position sensing is absolutely necessary.

**[0016]** To the contrary, the inventors of the present invention studied in detail the relation between the attraction force of the electromagnet applied to the steel sheet and the force applied to the warped steel sheet, and derived the findings described below.

1) The steel sheet, which was bent in the longitudinal direction caused by the contacting rolls or the like, warps in the width direction at the exit of the rolls. For example, according to the apparatus for producing a hot-dip galvanized steel sheet of the related art, which is shown in Fig. 1, the steel sheet S is subjected to bending in the longitudinal direction thereof by a sink roll 3 or support rolls 7 in the coating bath 2, and is warped in the width direction thereof.

The magnitude of warp depends on the radius of bend of the steel sheet given by the roll, the contact angle on the roll, the friction force with the roll, the tension, thickness, width, and kind of the steel sheet, and other variables. The force required to correct the warp also depends on these variables.

2) The case of correcting the warp on the steel sheet using electromagnets is shown in Fig. 2. The steel sheet S which was warped in the width direction as shown with broken line is subjected to magnetic force which is induced by applying a specified value of current to the electromagnets 5 located facing the steel sheet S at near the respective edges in width direction thereof. The steel sheet S receives a force, or an attractive force, of moving thereof toward the respective electromagnets 5. As a result, the edges of the steel sheet S in the width direction give a displacement X, and the steel sheet S becomes to a state shown by solid line in Fig. 2. At this moment, the steel sheet S is subjected to a force of returning the steel sheet to the original state, (dotted line), or subjected to the recovery force. Consequently, the steel sheet S is settled to a state that the attraction force and the recovery force are balanced with each other.

**[0017]** Fig. 3 shows a relation between the displacement of steel sheet and the force applied to the steel sheet, which relation was derived from the data acquired from a test apparatus simulating actual line. The displacement of steel sheet on the horizontal axis of Fig. 3 corresponds to the displacement X of Fig. 2.

**[0018]** As described above, the attraction force of the electromagnet 5 is inversely proportional to the square of distance between the steel sheet S and the electromagnet 5, and the recovery force of the steel sheet S is proportional to the displacement X thereof. With an adequate value of current applied to the electromagnet 5, the curve signifying the attraction force of the electromagnet 5 and the straight line signifying the recovery force of the steel sheet S intercept to each other at two points, as shown in Fig. 3. Considering the direction of resultant force, one of these two points gives the stable neutral point, while another one gives the instable neutral point. When the steel sheet S becomes closer to the electromagnet 5 than the instable neutral point, the attraction force always acts stronger than the recovery force so that the steel sheet S is further attracted to become caught by the electromagnet 5. If, however, the steel sheet S is further distant from the electromagnet 5 beyond the instable neutral point, the steel sheet S surely returns to the stable neutral point. The phenomena show that the warp of the steel sheet S is settled to a stable state by applying an adequate current to the electromagnet 5 to generate adequate attraction force therefrom. The stable neutral point is a point that the attraction force and the recovery force are balanced, and is not necessarily a point that the warp of the steel sheet S is corrected and the steel sheet S is flattened. Nevertheless, the steel sheet S can be flattened at the neutral point by optimizing the current value applied to the electromagnet 5.

**[0019]** As described above, a stable neutral point exists between the recovery force and the attraction force, and the shape-correction using the magnetic force of the electromagnets 5 can be brought to the "stable system", not the "instable system". The fact suggests that the current control of the electromagnet 5 not necessarily requires the feedback control by a position sensor, but is able to apply preset control which determines an adequate current value in advance.

**[0020]** Based on the above-described findings, a hot-dip metal coated steel sheet is produced by a method comprising the steps of: continuously introducing the steel sheet in a hot-dip metal coating bath of a molten metal to adhere the molten metal onto a surface of the steel sheet; changing the running direction of the steel sheet using a direction-changing device located in the hot-dip metal coating bath, and then taking the steel sheet out from the bath; adjusting a coating weight of the molten metal adhered to the steel sheet using a gas-wiping device; correcting a warp appeared on the steel sheet in non-contact state by magnetic force using an electromagnet positioned at upstream side and/or downstream side of the gas-wiping device, the electromagnet applying the magnetic force to the steel sheet in the direction crossing the surface thereof; and setting a current value of electromagnet to a current value preliminarily determined on the basis of information relating to the steel sheet. The method suppresses the generation of warp over the whole length of the steel sheet, thereby producing a hot-dip metal coated steel sheet having uniform coating weight and excellent surface property.

**[0021]** When the joint between the forerunning steel sheet and the succeeding steel sheet passes the position of the electromagnet, the current value applied to the electromagnet may be changed to a current value preliminarily determined on the basis of information relating to the succeeding steel sheet.

**[0022]** If a shape measuring device of the steel sheet and/or a measuring device to determine the coating weight of the molten metal adhered to the steel sheet is located downstream the gas-wiping device, and if the current value of electromagnet is adjusted on the basis of information determined by the shape measuring device of the steel sheet and/or the coating weight measuring device, the generation of warp is more effectively suppressed over the whole length of the steel sheet, thus assuring uniform coating weight.

**[0023]** If the direction-changing device for the steel sheet is the sole steel-supporting device in the hot-dip metal coating bath, without applying supporting roll or the like, the generation of flaws and defects on the steel sheet caused by dross in the coating bath decreases.

**[0024]** The method for producing the hot-dip metal coated steel sheet is realized by an apparatus which has: a hot-

dip metal coating bath of molten metal for adhering the molten metal onto the surface of the steel sheet; a direction-changing device located in the hot-dip metal coating bath tank to change the running direction of the steel sheet; a gas-wiping device positioned above the surface of the coating bath of the hot-dip metal coating bath tank to adjust the coating weight of the molten metal adhered to the steel sheet; electromagnets positioned at upstream side and/or downstream side of the gas-wiping device to apply magnetic force to the steel sheet in the direction crossing the surface thereof, thus correcting a warp appeared on the steel sheet in non-contact state; and a current value preset control device to set the current value of the electromagnet to a current value preliminarily determined on the basis of information relating to the steel sheet. If a shape measuring device of the steel sheet and/or a measuring device to determine the coating weight of the molten metal adhered to the steel sheet is located downstream the gas-wiping device, the generation of warp is suppressed and the uniformize of coating weight is more effectively attained.

## EMBODIMENT 1

**[0025]** Fig. 4 shows an example of apparatus for producing hot-dip metal coated steel sheet according to the present invention.

**[0026]** The apparatus for producing hot-dip metal coated steel sheet has: a hot-dip metal coating tank 1 which holds the hot-dip metal coating bath 2 to which the steel sheet S is drawn in to adhere the molten metal to the steel sheet; the gas-wiping device 4 which adjusts the coating weight of molten metal adhered to the steel sheet S after drawn up from the coating bath 2; the electromagnets 5; and support rolls 6 outside the bath. The apparatus further has a current control device 8, a preset control computer 9; and a line control device 10, as the control devices for the electromagnets 5.

**[0027]** The hot-dip metal coating bath tank 1 has the sink roll 3 as the direction-change device which changes the running direction of the steel sheet s in the coating bath 2. Furthermore, the tank 1 may have the support rolls 7 which support the steel sheet s in the coating bath 2 after changed the running direction thereof. Although the support rolls 7 have an effect of suppressing vibration and correcting warp of the steel sheet, they may induce dross defects on the steel sheet S by catching dross in the coating bath, in some cases. According to the present invention, however, since the electromagnets 5 fully conduct the suppression of vibration and the correction of warp, the support rolls 7 are not necessarily required, and rather they are preferably not applied from the point of prevention of surface defects on the steel sheet S.

**[0028]** The gas-wiping device 4 and the electromagnets 5 are located between the surface of coating bath 2 and the support rolls 6 outside the bath. The electromagnets 5 are positioned above and/or below the gas-wiping device 4. Since, however, zinc is emitted to deposit at downstream side of the gas-wiping device 4, the electromagnets 5 are preferably located to above the gas-wiping device 4.

**[0029]** According to the related art, the distance between the front end of the gas injection opening (wiping nozzle) of the gas-wiping device 4 and the steel sheet S is about 15 mm to prevent contact between the wiping nozzle and the steel sheet in case that the warp condition of steel sheet suddenly changes at the joint between the forerunning steel sheet and the succeeding one. Since, however, the present invention can correct the warp over the whole length of the steel sheet, the conventional distance 15 mm between the front end of the wiping nozzle and the steel sheet S can be decreased..

**[0030]** The electromagnet 5 is positioned facing the steel sheet surface to generate magnetic force in the direction crossing the surface of the steel sheet. The electromagnet 5 has functions of suppressing the vibration of the steel sheet s and of correcting the warp generated on the steel sheet S caused by the deformation under bending and returning given by the sink roll 3 and the support rolls 7 in the coating bath. Furthermore, as shown in Fig. 5, plurality of electromagnets 5 is arranged in the width direction of the steel sheet, for example, and the selected number thereof is used depending on the magnitude of the warp in the width direction.

**[0031]** The apparatus using electromagnets in the related art requires a position sensor to determine the position of the steel sheet. Since, however, the present invention applies what is called the "preset control", that kind of position sensor is not necessarily required. From the viewpoint of cost and of size of apparatus, the position sensor is preferably eliminated.

**[0032]** The steel sheet s immersed in the coating bath 2 is changed the running direction by the sink roll 3, and is drawn up from the coating bath 2, and then the coating weight thereon is adjusted by the gas-wiping device 4. At that moment, the steel sheet s passed the sink roll 3 is supported by the support rolls 7 in the bath and by the support rolls 6 outside the bath, while the vibration of the steel sheet s is suppressed by the magnetic force generated from the electromagnets 5 positioned between these support rolls, and also the warp is corrected thereby.

**[0033]** The current control of the electromagnet 5 is carried out by the steps described below. First, data of various kinds of operating conditions is transmitted from the line control device 10 to the preset control computer 9. Based on the data of operating conditions, the preset control computer 9 determines the current value for the preset control. The method for determining the current value may be the one using a preliminarily prepared table value or the one using

computation with a model formula prepared in advance. As for the method of using table value, an adequate current value (current value to make the steel sheet flat at the stable neutral point) is preliminarily determined for each operating condition, and thus determined current value is applied to the operating condition. The operating conditions may take into account of the thickness, width, kind, and tension of the steel sheet, the diameter, contact angle, and friction force of upstream roll, the feed rate to the roll, and the like. The model formula may be derived from a physical model which expresses the generation of warp, the attraction force of electromagnet, and the like, or may be derived by applying multiple regression analysis to the operating conditions. Thus calculated optimum current value is sent to the current control device 8. The current control device 8 generates a command to control the output of electromagnet 5. When the joint between the forerunning steel sheet and the succeeding steel sheet passes the position of the electromagnet 5, the current value applied to the electromagnet 5 may be changed to a current value preliminarily determined on the basis of information of the succeeding steel sheet.

**[0034]** Fig. 6 shows an example of preset control flow diagram according to the present invention.

**[0035]** The flow shown by solid line is the flow of preset control applied to the forerunning steel sheet under the treatment described above.

**[0036]** Regarding the succeeding steel sheet, as shown by broken line, the operating conditions for the succeeding steel sheet, transmitted from the line control device 10, are used to calculate the optimum current value by the preset control computer 9 using table value or model formula. The preset control computer 9 receives the signal from the line control device 10 notifying that the joint between the forerunning steel sheet and the succeeding steel sheet passes the point of the gas-wiping device 4 or the electromagnets 5, and generates the optimum current value for the electromagnets 5 to the current control device 8. As a result, from the time that the front end of the succeeding steel sheet passes the point of gas-wiping device or electromagnets, the current value of electromagnet 5 is set to the optimum value.

**[0037]** As described above, the application of preset control as the current control of the electromagnet 5 allows the warp correction over the whole length of the steel sheet including the joint between the forerunning steel sheet and the succeeding steel sheet and nearby sections thereof. Furthermore, since no support roll 7 in the bath is applied, the preset model can further be simplified. In addition, it is possible to prevent the generation of surface defects caused by the rolls in the bath and to decrease the maintenance cost for the rolls. Since, furthermore, the front end of the wiping nozzle of the gas-wiping device 4 and the steel sheet S can be brought to close with each other, the operation under low gas pressure is available to suppress the generation of splash defects.

## EMBODIMENT 2

**[0038]** Fig. 7 shows another example of apparatus for producing hot-dip metal coated steel sheet according to the present invention.

**[0039]** The apparatus for producing hot-dip metal coated steel sheet has the structure of the apparatus given in Fig. 4, and further has a steel sheet shape measuring device 11 located near the gas-wiping device 4, a coating weight measuring device 12 located downstream the support rolls 6 outside the bath, and a feedback control computer 13 as a control device for the electromagnets 5. With the apparatus, adding to the preset control described in the First mode, what is called the "feedback control" can be conducted. The feedback control recognizes the warp of steel sheet on the basis of information determined by the shape measuring device 11 and/or the coating weight measuring device 12, thus changes the current value of electromagnet 5.

**[0040]** Since the shape measuring device 11 and the coating weight measuring device 12 are installed to recognize the condition of vibration and warp of the steel sheet S, both of them are not necessarily applied.

**[0041]** The shape measuring device 11 determines the magnitude of warp of the steel sheet S, and the device 11 is not necessarily requested to measure the whole width of the steel sheet S. For example, the device 11 may be a position sensor that measures only the central section and the edges in the width direction of the steel sheet S. To determine the shape at the position of gas-wiping device 4, the shape measuring device 11 is preferably close to the gas-wiping device 4 as far as possible. Furthermore, the shape measuring device 11 is preferably positioned above the gas-wiping device 4 to avoid the influence of emitted zinc.

**[0042]** The coating weight measuring device 12 determines the coating weight on the steel sheet S and determines the distribution of coating weight in the width direction of the steel sheet S. Based on the distribution of coating weight, the distance between the gas-wiping device 4 and the steel sheet S, or the warp of the steel sheet S, can be estimated.

**[0043]** First, the shape of steel sheet S is determined by the shape measuring device 11, or the distribution of coating weight on the surface of steel sheet in the width direction is determined by the coating weight measuring device 12. The acquired information is transmitted to the feedback control computer 13 to derive the warp of the steel sheet S. Then, based on the data of various operating conditions sent from the line control device 10, the changing value of current which is set in the feedback control is determined. The changing value may, similar with the preset control, be determined based on the preliminarily prepared table value or may be determined by structuring a model formula. Thus

calculated changing value for the current is transmitted to the current control device 8, and the command generated from the current control device 8 controls the output of electromagnet 5.

[0044] Fig. 8 shows an example of feedback control flow diagram according to the present invention.

[0045] The flow expressed by solid line is the preset control flow described in the First mode.

[0046] According to the feedback control, as shown by broken line, the shape data determined by the shape measuring device 11 or the data of distribution of coating weight in the width direction of the steel sheet, determined by the coating weight measuring device 12, are transmitted to the feedback control computer 13. If the coating weight measuring device 12 is applied, the relation between the distribution of coating weight in the width direction and the shape of steel sheet is determined in advance, and the shape of the steel sheet is determined based on the relation. The warp of the steel sheet is calculated from the shape data. Using the various operating conditions generated from the line control device 10, the feedback control computer 13 calculates the changing value of the current of electromagnet 5 using the table value or the model formula. Then, the changing value for the current is sent to the current control device 8.

[0047] The preset control described in the First mode actualizes almost flat steel sheet. However, error in the preset accuracy may occur from indeterminate causes such as error in model and wear of roll. In that case, further feedback control may be given to measure the actual warp of the steel sheet, and the output of electromagnet is corrected by the measured value to obtain more flat steel sheet. It is preferable to consider that kind of preset error and to conduct error-learning reflecting the error to the succeeding preset.

[0048] Fig. 9 compares the shape controllability between the present invention and the related art.

[0049] Since the related art applies only the feedback control, the warp at the front end of succeeding steel sheet cannot be corrected at the joint between the forerunning steel sheet and the succeeding steel sheet.

[0050] To the contrary, the First mode according to the present invention suppresses the warp to a specified range over the whole length of the steel sheet owing to the preset control.

[0051] According to the Second mode of the present invention, feedback control is given adding to the preset control so that the error generated in the preset control can be corrected, thus the steel sheet is controlled to flat shape almost whole length thereof.

[0052] The First mode and the Second mode described the method of conducting the control of the current of electromagnet 5. The adjustment of the magnetic force of electromagnet 5 is, however, attained also by adjusting the distance between the electromagnet 5 and the steel sheet. Accordingly, instead of applying the control of current of the electromagnet 5, similar effect is attained by adjusting the distance between the electromagnet 5 and the steel sheet.

[0053] In addition, the First mode and the Second mode can correct the warp over the whole length of the steel sheet, and the generation of surface defects caused by the roll immersed in the bath is prevented without using support roll in the bath, and further the generation of splash defects is prevented by decreasing the distance between the front end of the wiping nozzle of gas-wiping device and the steel sheet. As a result, the First mode and the Second mode are able to manufacture high quality hot-dip galvanized steel sheet.

[0054] The description given above explains the application to the manufacture of general hot-dip galvanized steel sheet. The present invention, however, is not limited to the explanation, and can be applied to the manufacture of other hot-dip metal coated steel sheets.

## EXAMPLES

[0055] Starting from a cold-rolled steel sheet as the coating substrate having 0.7 mm of thickness and 1500 mm of width, the hot-dip galvanized steel sheet coils were prepared using the apparatuses for producing hot-dip metal coated steel sheet according to the present invention, shown in Fig. 4 and Fig. 10, respectively, under the four kinds of conditions of electromagnet and sensor, given in Table 1.

[0056] Under the condition of Example 1 according to the present invention, the preset control of electromagnet was given by the producing apparatus of Fig. 4. The apparatus does not need special sensor and has a simple facility configuration so that the electromagnets were positioned above the wiping nozzle by 250 mm therefrom, or close to the wiping nozzle. The distance between the wiping nozzle and the steel sheet was as narrow as 7 mm. As for the support roll immersed in the bath, both cases of use and not-use were studied.

[0057] Under the conditions of Example 2 and Example 3 according to the present invention, the preset control of electromagnet and the feedback control thereof were given by the producing apparatus of Fig. 7. As for the sensor, Example 2 used the shape measuring device, and Example 3 used the coating weight measuring device. Regarding the electromagnets, since the shape measuring device was located near and above the wiping nozzle in Example 2, the electromagnets were positioned above the wiping nozzle by 500 mm therefrom. In Example 3, however, the electromagnets were positioned above the wiping nozzle by 250 mm therefrom. The distance between the wiping nozzle and the steel sheet was 7 mm, which is narrow. For the support roll immersed in the bath, both cases of use and not-use were studied, similar with Example 1.

[0058] Under the condition of Comparative Example, the feedback control of electromagnet according to the related art was conducted using the conventional producing apparatus of Fig. 9 applying the electromagnets and the nearby shape measuring device. Since the shape measuring device was applied, the electromagnets were positioned above the wiping nozzle by 500 mm therefrom. The distance between the wiping nozzle and the steel sheet was 15 mm. For the support roll immersed in the bath, only the use-case was studied.

[0059] With thus prepared hot-dip galvanized steel sheets, the generation of splash defects and the distribution of coating weight in the width direction were investigated. Regarding the generation of splash defects, a surface defect meter mounted to the hot-dip galvanizing line was used to give evaluation by the total number of splash defects over the whole length of the steel sheet coil. As for the distribution of coating weight in the width direction, a coating weight meter mounted to the hot-dip galvanizing line was used to give evaluation by measuring the distribution of coating weight in the width direction of the steel sheet.

[0060] The investigation showed that, for the generation of splash defects, the number of splashes generated in a single steel sheet coil was about 10 in Comparative Example, while the number thereof in Examples 1 to 3 was one or two under the all tested conditions, which number is significantly small compared with that in Comparative Example. The superiority comes from that the distance between the wiping nozzle and the steel sheet was 15 mm in Comparative Example, and that of Examples was decreased to 7 mm to allow the gas wiping to apply at low gas pressures. In Examples 1 to 3, no difference between the use and the not-use of roll immersed in the bath was observed.

[0061] As for the distribution of coating weight in the width direction at the front end of the steel sheet, Comparative Example gave about  $\pm 10$  g/m<sup>2</sup> of coating weight, which is non-uniform, while Examples 1 to 3 showed almost uniform coating weight at around  $\pm 3$  g/m<sup>2</sup>. The superiority comes from that, Comparative Example which used the feedback control of electromagnet could not respond to the changes of warp at the front end of succeeding steel sheet at the joint between the forerunning steel sheet and the succeeding steel sheet, and that Examples 1 to 3 which applied the preset control of electromagnet could adequately correct the warp on and after the front end of succeeding steel sheet.

[0062] For the distribution of coating weight in the width direction at central portion of the steel sheet along the longitudinal direction, Example 1 gave the coating weight of about  $\pm 3$  g/m<sup>2</sup> similar with that at the front end of the steel coil, and Examples 2 and 3 gave an improvement to about  $\pm 1$  to 2 g/m<sup>2</sup> of the coating weight. The improvement comes from that Example 1 which applied only the preset control of electromagnet left some degree of warp in some cases caused by the error of feedback control, though the warp of steel sheet could almost be flattened, while Examples 2 and 3 which conducted the feedback control adding to the preset control of electromagnet could correct the shape, even when the preset control generated error, by correcting the error by the feedback control.

Table 1

	Example 1	Example 2	Example 3	Comparative Example
Electromagnet	Use	Use	Use	Use
Method of electromagnet control	Preset	Preset + Feedback	Preset + Feedback	Feedback
Sensor	Not-use	Shape measuring device	Coating weight measuring device	Shape measuring device
Position of electromagnet (above the nozzle)	250mm	500mm	250mm	500mm
Distance between nozzle and steel sheet	7mm	7mm	7mm	15mm
Support roll immersed in bath	Use/Not-use	Use/Not-use	Use/Not-use	Use

**Claims**

1. A method for producing a hot-dip metal coated steel sheet, comprising the steps of:

continuously introducing a steel sheet in a hot-dip metal coating bath of a molten metal to adhere the molten metal onto a surface of the steel sheet;

changing a running direction of the steel sheet using a direction-changing device located in the hot-dip metal coating bath, and then taking the steel sheet out from the bath;  
 adjusting a coating weight of the molten metal adhered to the steel sheet using a gas-wiping device;  
 correcting a warp appeared on the steel sheet in non-contact state by magnetic force using an electromagnet positioned at upstream side and/or downstream side of the gas-wiping device, the electromagnet applying the magnetic force to the steel sheet in the direction crossing the surface thereof; and  
 setting a current value of the electromagnet to a predetermined current value on the basis of information relating to the steel sheet.

2. The method according to claim 1, further comprising the step of changing the current value of the electromagnet, on passing a joint of forerunning steel sheet and succeeding steel sheet through the position of the electromagnet, to a predetermined current value on the basis of information relating to the succeeding steel sheet.

3. The method according to claim 1, further comprising the steps of:

positioning a shape measuring device of the steel sheet and/or a coating weight measuring device thereof downstream the gas-wiping device; and  
 adjusting the current value of the electromagnet on the basis of information determined by the shape measuring device and/or the coating weight measuring device.

4. The method according to claim 1, further comprising the step of:

positioning a shape measuring device of the steel sheet and/or a coating weight measuring device thereof downstream the gas-wiping device; and  
 adjusting the current value of the electromagnet on the basis of information determined by the shape measuring device and/or the coating weight measuring device.

5. The method according to claim 1, wherein the direction-changing device for the steel sheet is a sole steel sheet supporting device in the hot-dip metal coating bath.

6. The method according to claim 2, wherein the direction-changing device for the steel sheet is a sole steel sheet supporting device in the hot-dip metal coating bath.

7. The method according to claim 3, wherein the direction-changing device for the steel sheet is a sole steel sheet supporting device in the hot-dip metal coating bath.

8. The method according to claim 4, wherein the direction-changing device for the steel sheet is a sole steel sheet supporting device in the hot-dip metal coating bath.

9. An apparatus for producing a hot-dip metal coated steel sheet, comprising:

a hot-dip metal coating bath tank for adhering a molten metal onto a surface of a steel sheet;  
 a direction-changing device located in the hot-dip metal coating bath tank to change the running direction of the steel sheet;  
 a gas-wiping device positioned above the surface coating bath of the hot-dip metal coating bath tank to adjust a coating weight of the molten metal adhered to the steel sheet;  
 an electromagnet positioned at upstream side and/or downstream side of the gas-wiping device to apply magnetic force to the steel sheet in the direction crossing the surface thereof to correct a warp appeared on the steel sheet in non-contact state;  
 and  
 a current value preset control device to set the current value of the electromagnet to a current value preliminarily determined on the basis of information relating to the steel sheet.

10. The apparatus according to claim 9, further comprising:

a shape measuring device for the steel sheet and/or a coating weight measuring device therefor, located downstream the gas-wiping device; and  
 a current value feedback control device to adjust the current value of the electromagnet on the basis of infor-

mation determined by the shape measuring device and/or the coating weight measuring device.

**11.** The apparatus according to claim 9, wherein the direction-changing device for the steel sheet is a sole steel sheet-supporting device in the hot-dip metal coating bath tank.

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**12.** The apparatus according to claim 10, wherein the direction-changing device for the steel sheet is a sole steel sheet-supporting device in the hot-dip metal coating bath tank.

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FIG. 1

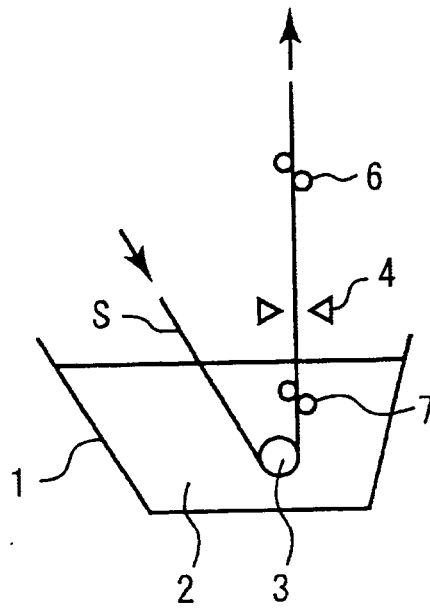


FIG. 2

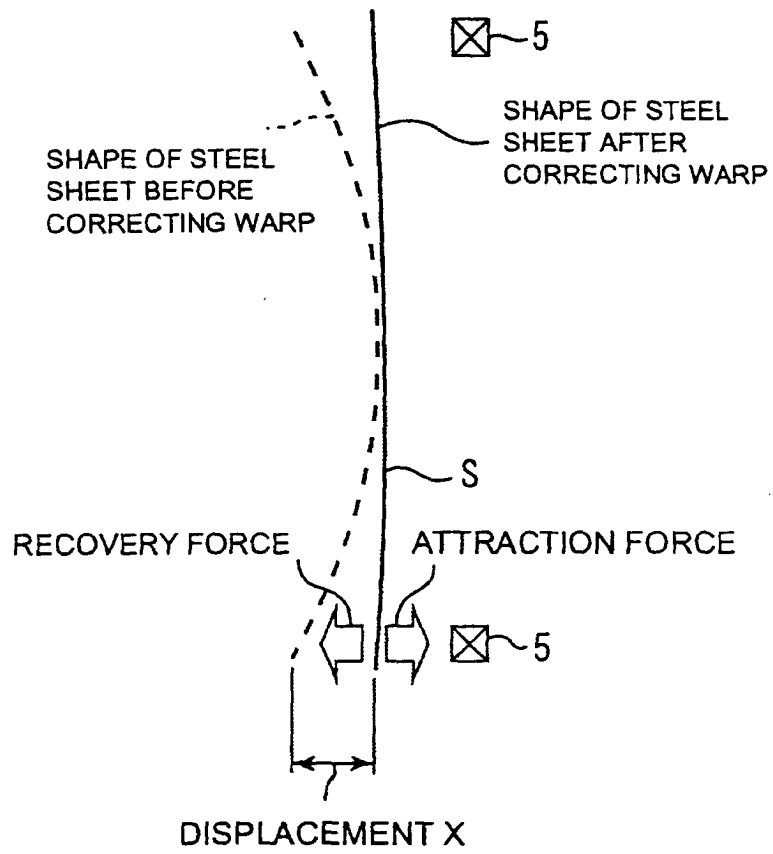


FIG. 3

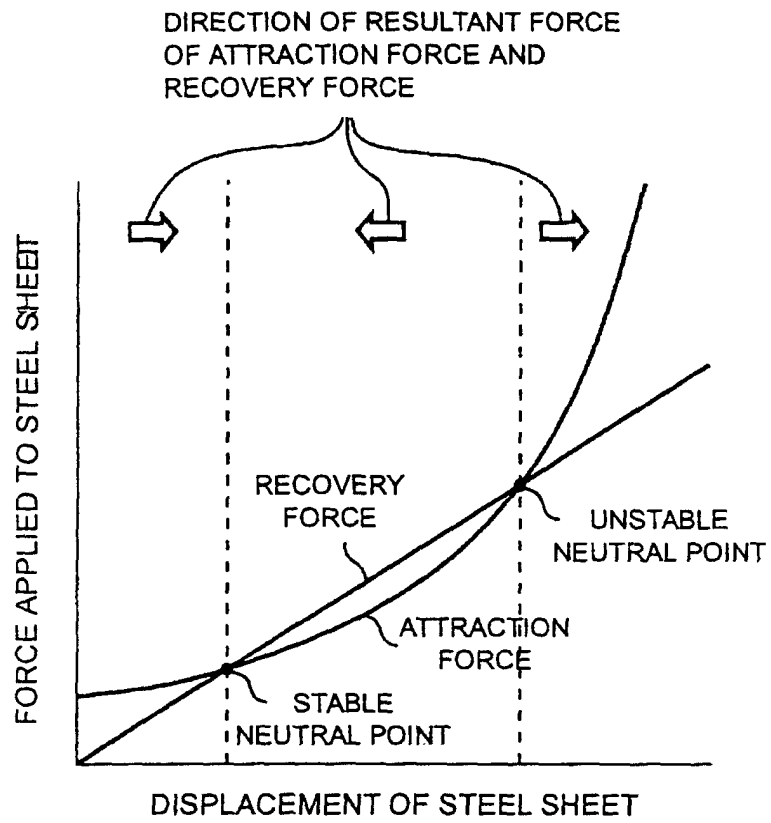




FIG. 5

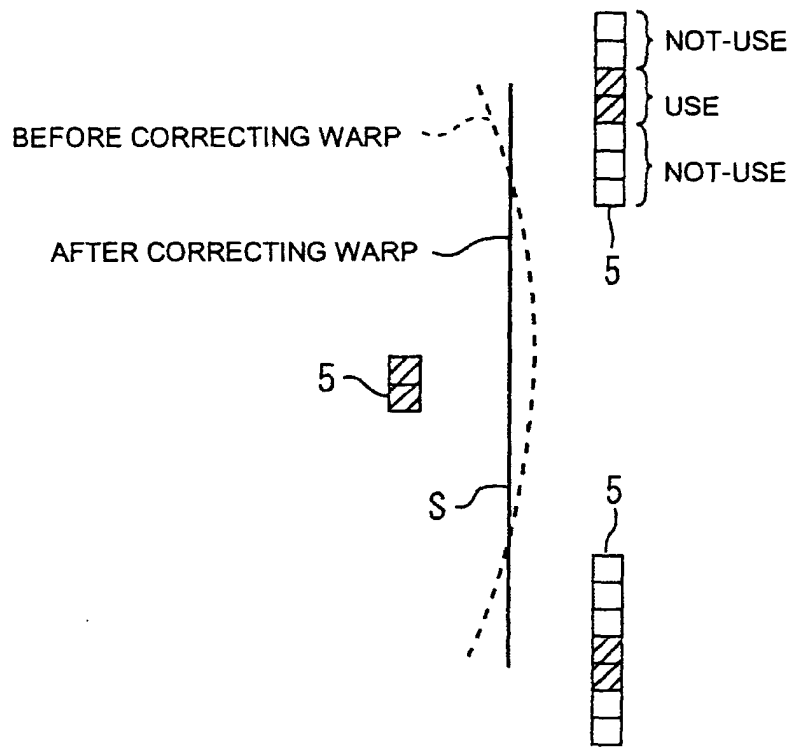


FIG. 6

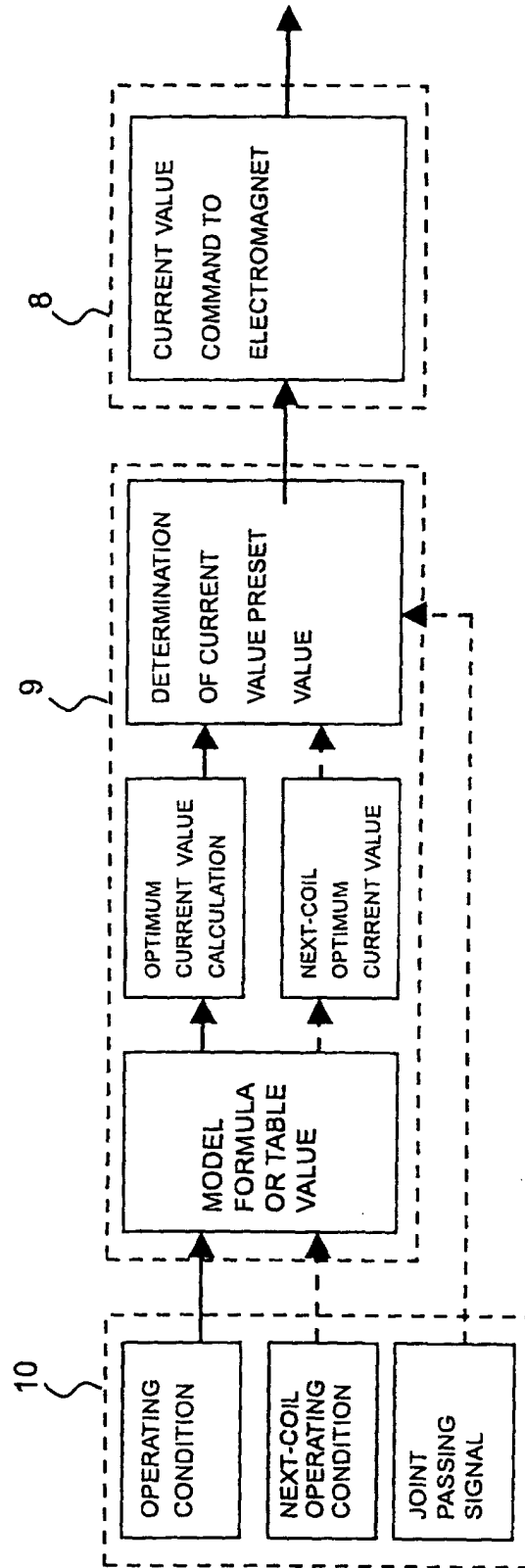


FIG. 7

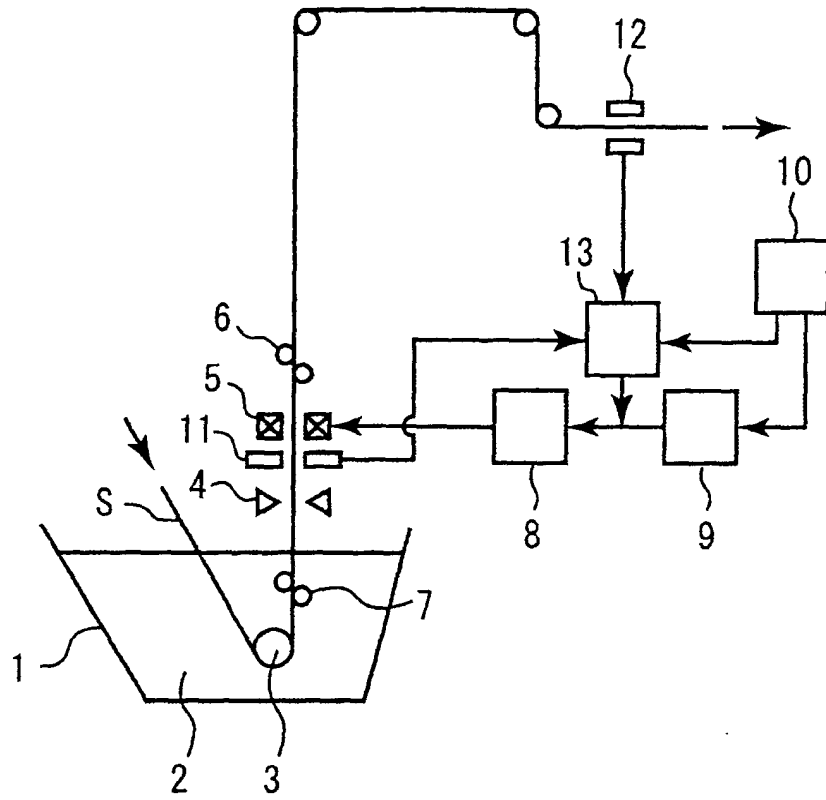


FIG. 8

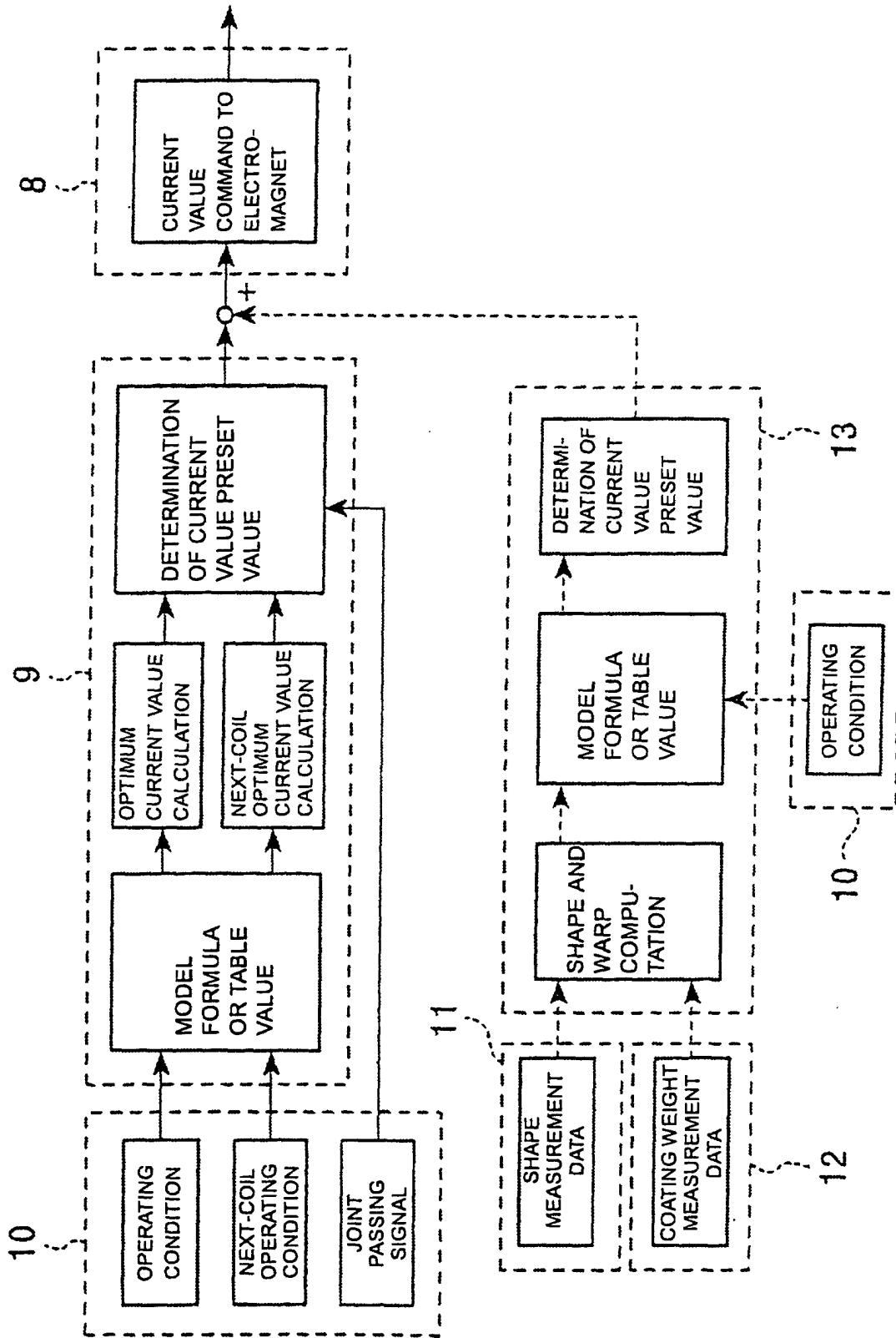
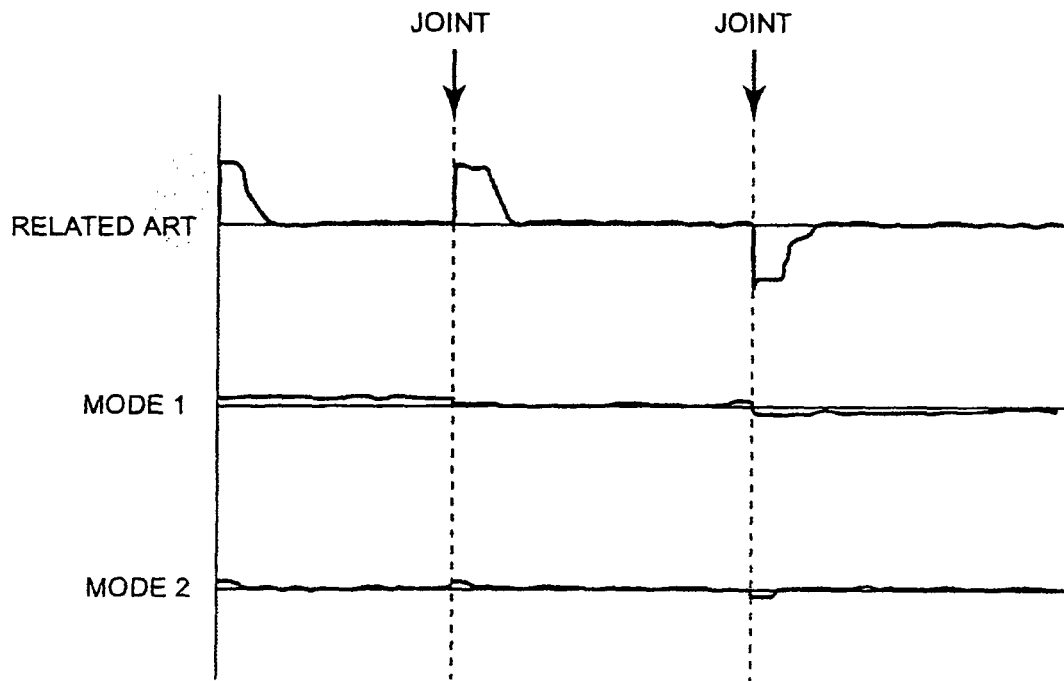


FIG. 9



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/07924

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. <sup>7</sup> C23C2/00		
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) Int.Cl. <sup>7</sup> C23C2/00-2/40		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2003 Kokai Jitsuyo Shinan Koho 1971-2003 Jitsuyo Shinan Toroku Koho 1996-2003		
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.
P, X	JP 2002-294426 A (Mitsubishi Heavy Industries, Ltd.), 09 October, 2002 (09.10.02), Claims; page 4, right column, lines 14 to 26; Figs. 1, 2 (Family: none)	1-4, 9, 10
X	EP 525387 A1 (NKK Corp.), 03 February, 1993 (03.02.93), Claims; page 9, line 58 to page 10, line 51; Figs. 25 to 29	1, 9
Y	& CA 2072200 A & CA 2072210 A & DE 69201466 C2 & JP 5-1359 A & JP 5-1360 A & JP 5-51719 A & KR 9500007 B & US 5384166 A	3, 5, 7, 10, 11, 12
A		2, 4, 6, 8
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	"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	
"A" document defining the general state of the art which is not considered to be of particular relevance	"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	
"E" earlier document but published on or after the international filing date	"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	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family	
"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		
Date of the actual completion of the international search 05 September, 2003 (05.09.03)	Date of mailing of the international search report 16 September, 2003 (16.09.03)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
Facsimile No.	Telephone No.	

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/07924

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-287736 A (Mitsubishi Heavy Industries, Ltd.), 11 October, 1994 (11.10.94), Claims; Figs. 1, 3 (Family: none)	3, 5, 7, 10, 11, 12
A	JP 9-25552 A (NKK Corp.), 28 January, 1997 (28.01.97), Claims; Figs. 1, 2 (Family: none)	1-12

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