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(19) **United States**(12) **Patent Application Publication**
TAKAHASHI(10) **Pub. No.: US 2018/0105916 A1**(43) **Pub. Date: Apr. 19, 2018**(54) **CONTINUOUS HOT-DIP METAL COATING
METHOD AND CONTINUOUS HOT-DIP
METAL COATING LINE***C22C 38/06* (2006.01)*C22C 38/04* (2006.01)*C22C 38/02* (2006.01)*C22C 38/00* (2006.01)(71) Applicant: **JFE STEEL CORPORATION**,
Chiyoda-ku, Tokyo (JP)*C23C 2/06* (2006.01)*C23C 2/40* (2006.01)(72) Inventor: **Hideyuki TAKAHASHI**, Chiyoda-ku,
Tokyo (JP)(52) **U.S. Cl.**CPC *C23C 2/003* (2013.01); *C21D 9/56*(2013.01); *C22C 38/06* (2013.01); *C23C 2/40*(2013.01); *C22C 38/02* (2013.01); *C22C**38/002* (2013.01); *C23C 2/06* (2013.01); *C22C**38/04* (2013.01)(73) Assignee: **JFE STEEL CORPORATION**,
Chiyoda-ku, Tokyo (JP)(21) Appl. No.: **15/565,986**(22) PCT Filed: **Feb. 25, 2016**(86) PCT No.: **PCT/JP2016/001013**

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Publication Classification(51) **Int. Cl.***C23C 2/00* (2006.01)*C21D 9/56* (2006.01)(57) **ABSTRACT**

A continuous hot-dip metal coating method that can reduce both non-coating caused by metal vapor generated in a snout and non-coating caused by an oxide film on a molten metal bath surface in the snout and stably and promptly change the oxidizability of the atmosphere in the snout is provided. In a continuous hot-dip metal coating method, oxidizing gas is supplied into a snout 14, a temperature of an inner wall surface of the snout is maintained at 150° C. or less below a temperature of the molten metal bath, and an atmospheric temperature of an upper portion in the snout is maintained at 100° C. or less below the temperature of the molten metal bath.

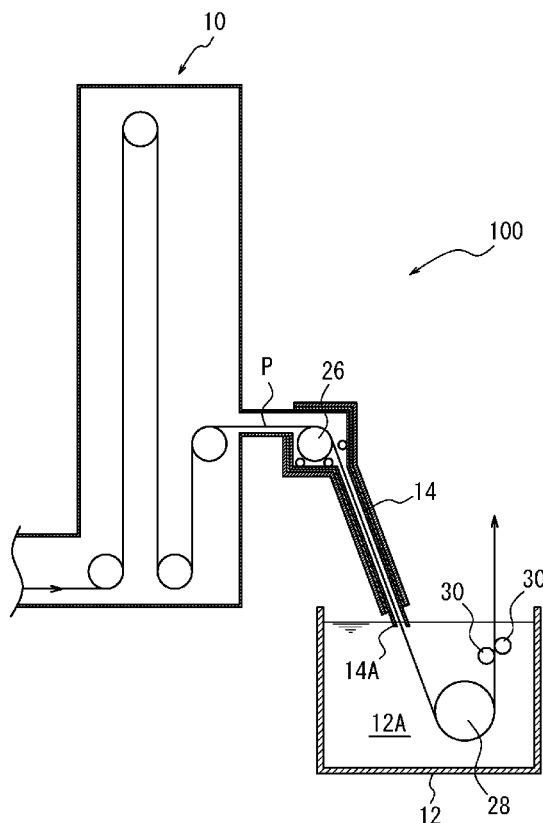


FIG. 1

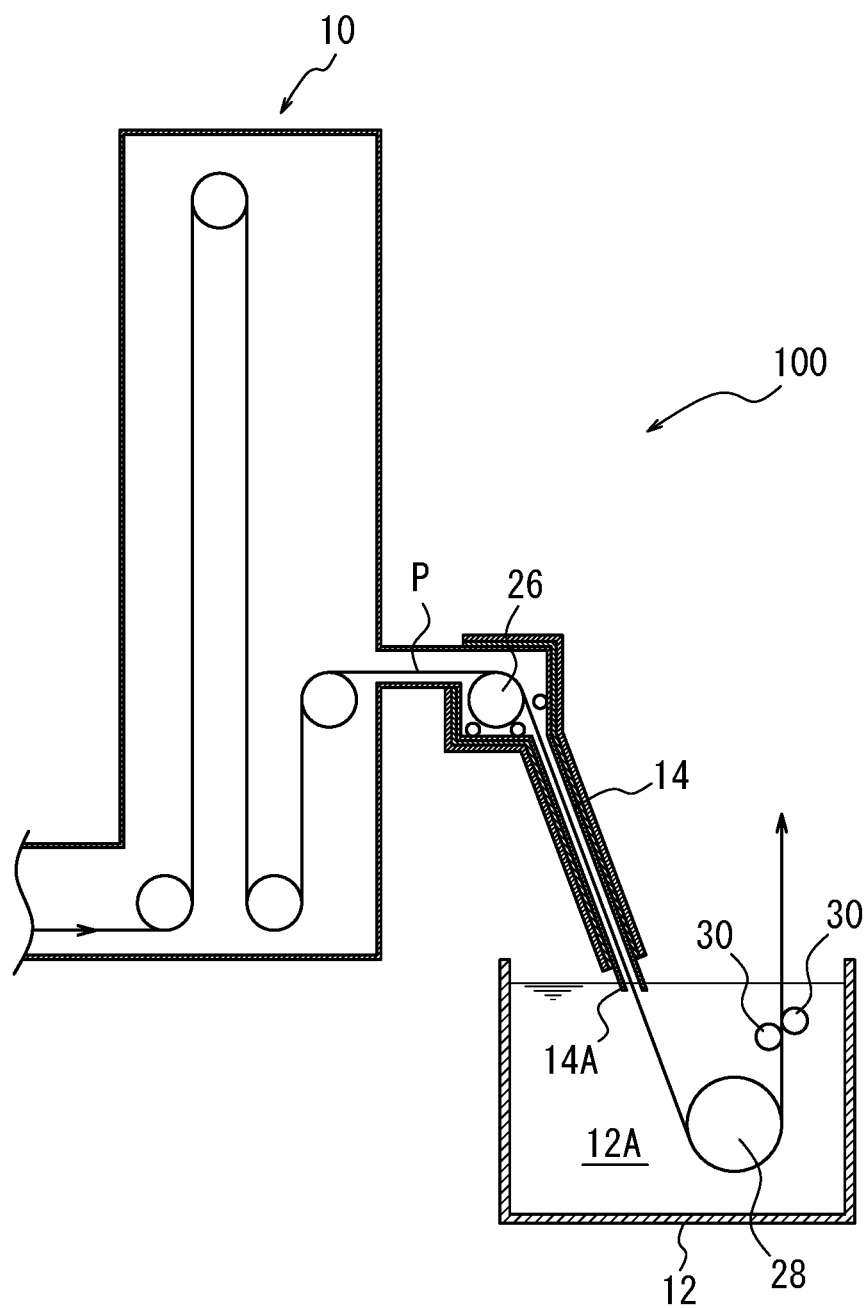


FIG. 2

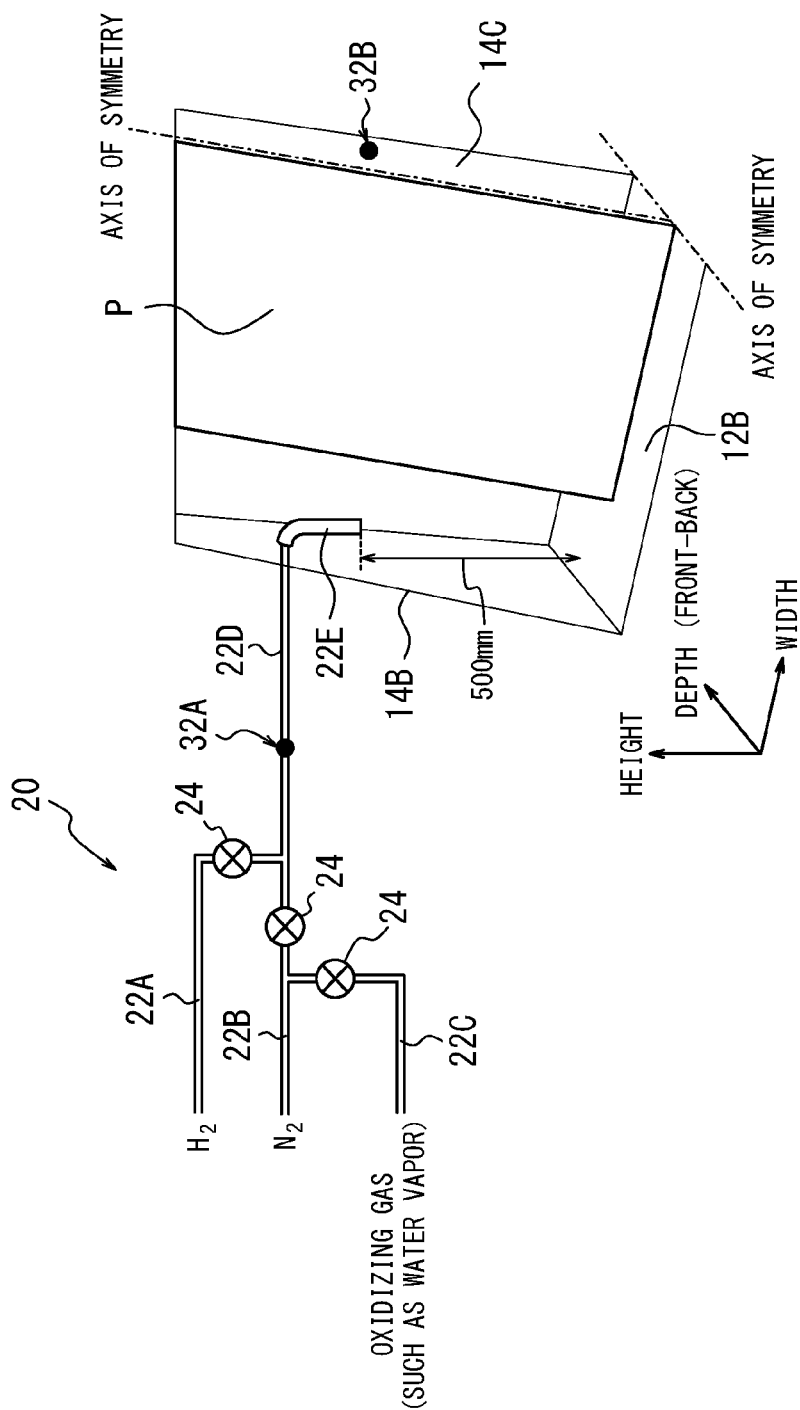


FIG. 3

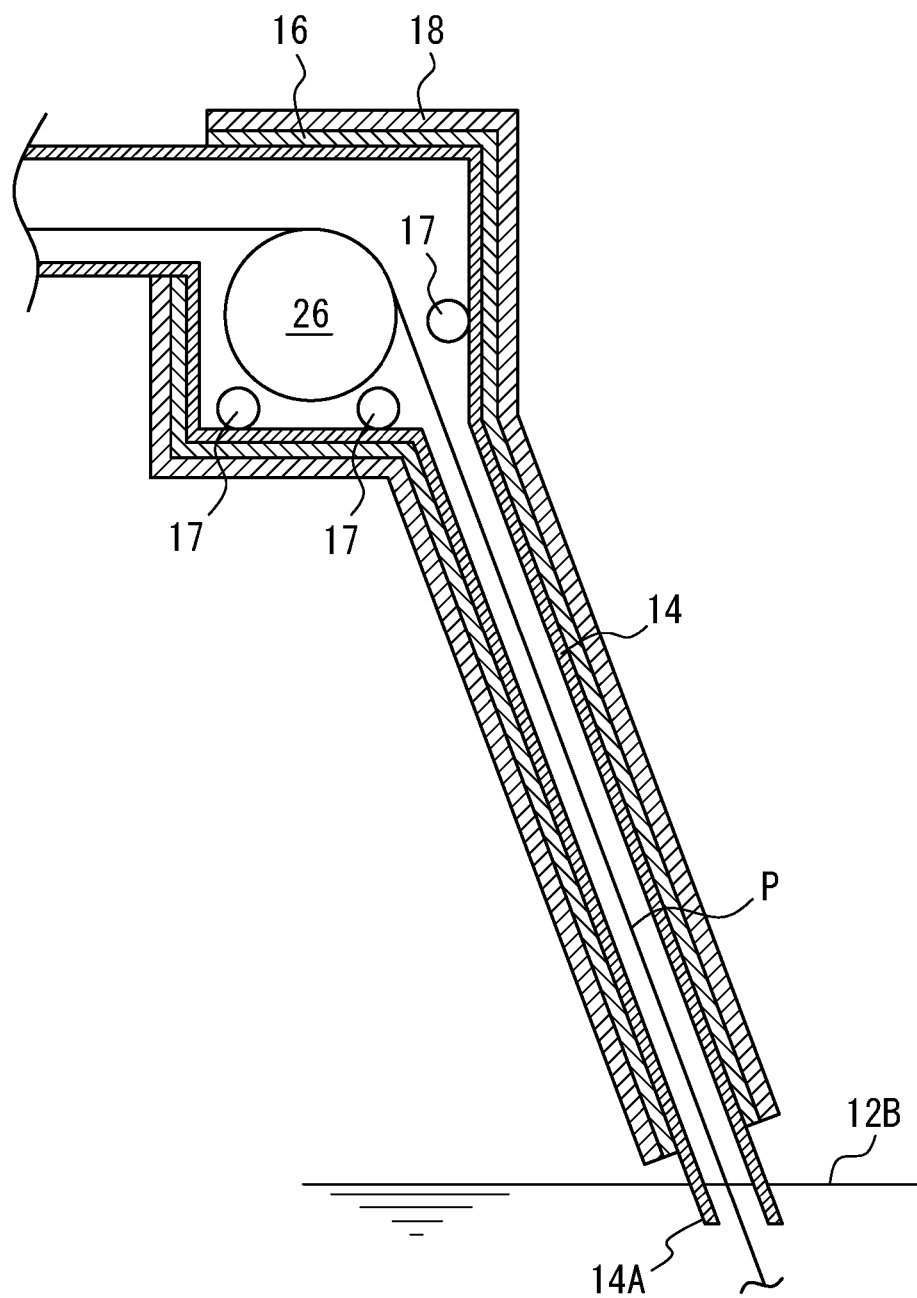


FIG. 4

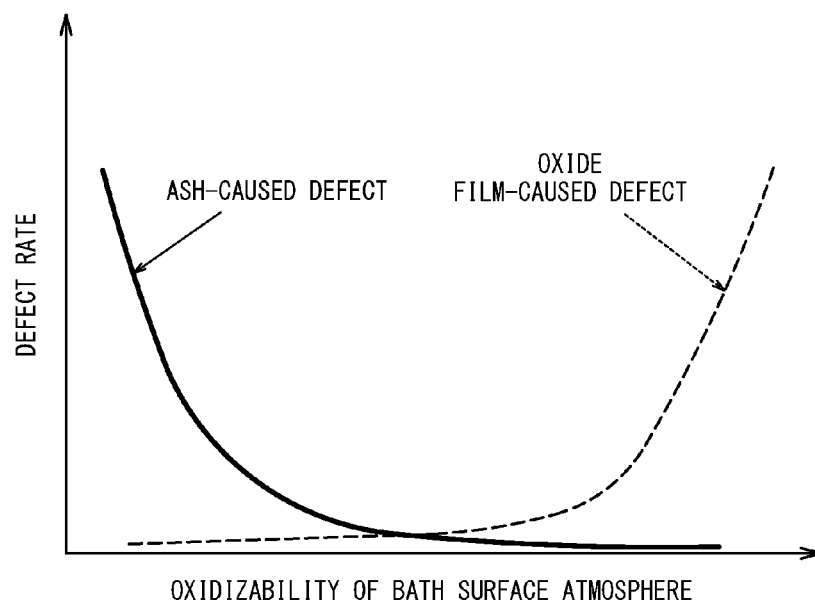


FIG. 5A

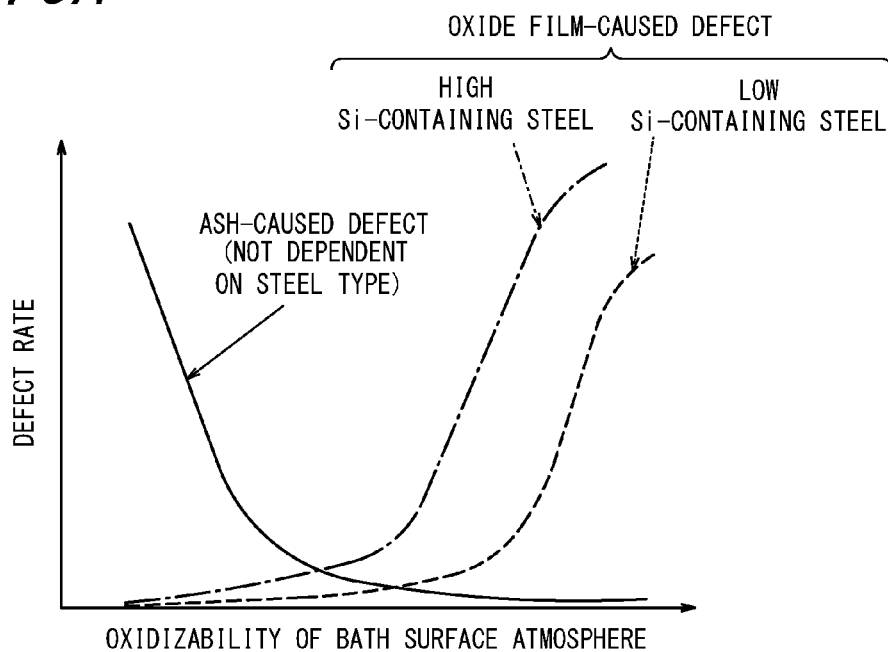


FIG. 5B

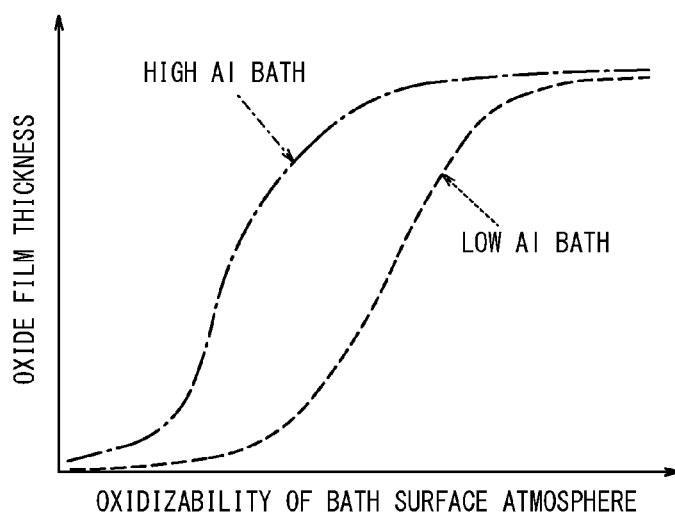


FIG. 6A

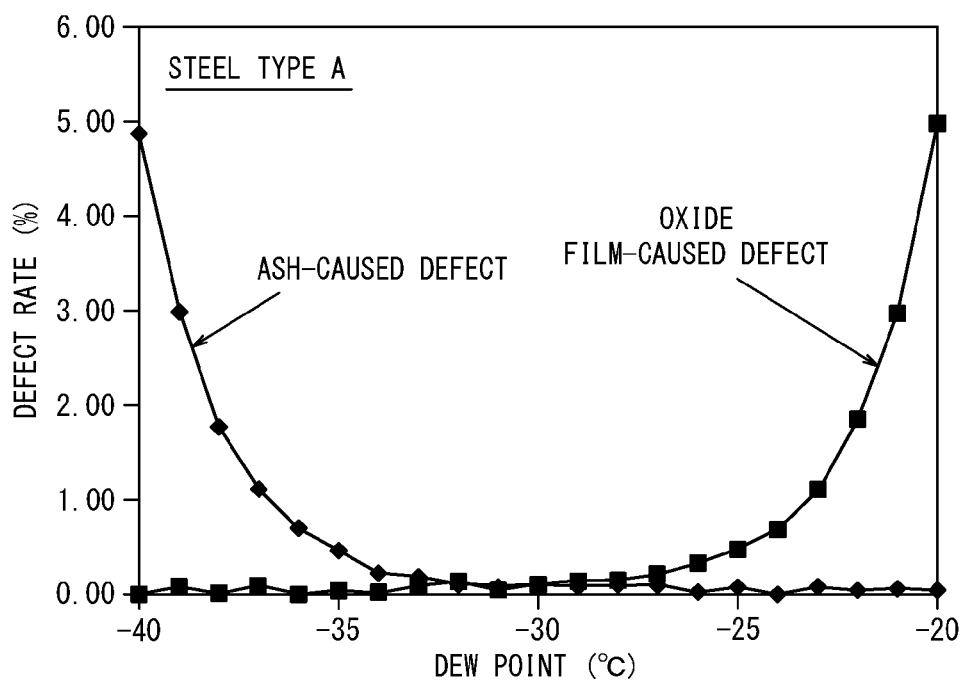


FIG. 6B

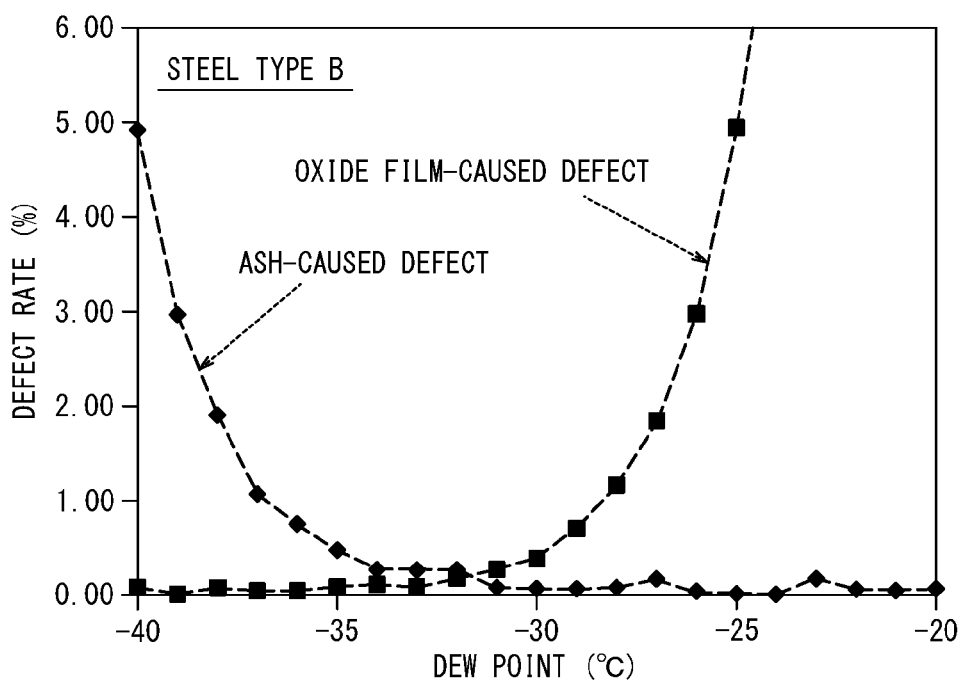
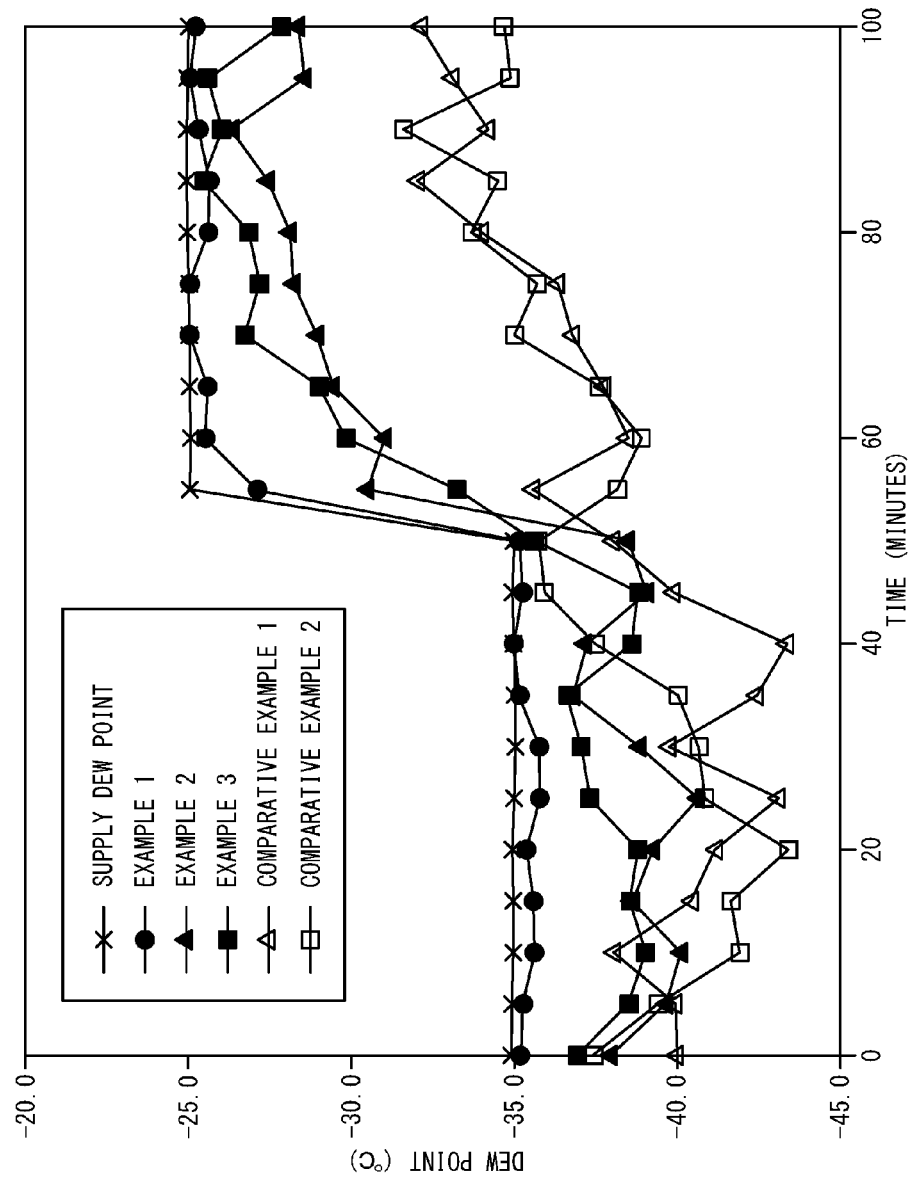


FIG. 7



CONTINUOUS HOT-DIP METAL COATING METHOD AND CONTINUOUS HOT-DIP METAL COATING LINE

TECHNICAL FIELD

[0001] The disclosure relates to a continuous hot-dip metal coating method and continuous hot-dip metal coating line used to continuously manufacture, for example, a hot-dip galvanized steel sheet.

BACKGROUND

[0002] In a continuous hot-dip galvanizing line for steel strips, typically, a steel strip whose surface has been cleaned is continuously annealed in an annealing furnace, and cooled to a predetermined temperature. The steel strip is then entered into a molten zinc bath, to be hot-dip galvanized. The annealing and cooling in the annealing furnace are typically performed in a reducing atmosphere. To block the steel strip passage from the air and enable the steel strip to pass in the reducing atmosphere while the steel strip leaves the annealing furnace and enters the molten zinc bath, a passage called a snout that is rectangular in section is provided between the annealing furnace and a coating tank containing the molten zinc bath. A sink roll is installed in the molten zinc bath. Having entered the molten zinc bath, the steel strip changes its traveling direction by the sink roll, and moves upward. The steel strip pulled up from the molten zinc bath is adjusted to have a predetermined coating thickness by gas wiping nozzles. After this, the steel strip is cooled, and guided to subsequent steps.

[0003] The snout is connected to a cooling zone (steel strip delivery side) in the annealing furnace, and so the inside of the snout normally has a reducing atmosphere. This makes the formation of an oxide film on the molten zinc bath surface in the snout difficult, and only a thin oxide film forms. The oxide film formed on the molten zinc bath surface in the snout is therefore not firm. Accordingly, when the steel strip enters the molten zinc bath, molten zinc is exposed on the bath surface due to vibration or the like, and zinc evaporates from the bath surface into the snout. In such a case, molten zinc evaporates to the saturation vapor pressure at the atmospheric temperature in the snout.

[0004] Zinc vapor reacts with oxygen present in a very small amount in the reducing atmosphere gas, to form an oxide. Even in the case where zinc vapor is not oxidized, when the vapor pressure of zinc vapor reaches the saturation vapor pressure or more, part of zinc vapor phase-changes to zinc in the liquid phase or the solid phase. In particular, since the snout is merely made of a thin heat-resistant material, the temperature of the inner wall surface of the snout tends to be less than or equal to the saturation temperature at the vapor pressure of zinc vapor due to the influence of external air. In a site where the temperature is less than or equal to the saturation temperature, zinc vapor becomes zinc powder and adheres to the inner surface of the snout.

[0005] If such oxide or deposit (ash) adheres to the steel strip, quality defects such as non-coating portions occur. Quality defects such as non-coating portions caused by ash generated due to zinc vapor in the snout are hereafter referred to as “ash-caused defects”.

[0006] The following techniques have been proposed to reduce ash-caused defects. JP H8-176773 A (PTL 1) describes a technique of heating the snout with a heater and

insulating the outside of the heater with a heat insulator so that the temperature difference between the molten bath temperature and each of the atmospheric temperature and inner wall temperature in the snout is 150° C. or less, thus preventing ash adhesion to the snout inner wall. JP H8-302453 A (PTL 2) describes a technique of installing a suction blower in the molten bath and connecting, to the suction side of the suction blower, a suction tube that has a suction port at a position higher than the bath surface in the snout, to discharge zinc vapor in the snout to outside the system. JP H6-330271 A (PTL 3) describes a technique of setting the atmosphere in the snout to non-oxidizing gas for a steel sheet and to oxidizing gas for molten zinc to suppress the generation of fumes (zinc vapor).

CITATION LIST

Patent Literatures

[0007] PTL 1: JP H8-176773 A

[0008] PTL 2: JP H8-302453 A

[0009] PTL 3: JP H6-330271 A

SUMMARY

Technical Problem

[0010] The technique in PTL 1 can reduce the crystallization of zinc vapor on the snout inner wall, that is, the generation of ash, to some extent by heating the snout. However, the generation of zinc vapor from the molten zinc bath surface itself cannot be prevented, and so ash is inevitably generated in a site that is not heated. The technique thus cannot eliminate a potential risk of ash adhering to the steel strip.

[0011] With the technique in PTL 2, zinc vapor in the snout cannot be discharged completely. Zinc vapor that has not been discharged adheres to the snout inner wall, resulting in the generation of ash. The effect of preventing ash-caused defects is thus insufficient. Besides, discharging zinc vapor rather facilitates the evaporation of molten zinc, and therefore tends to be not effective.

[0012] With the technique in PTL 3, since there is considerably rapid gas convection in the snout, most of the supplied oxidizing gas is released from the system without staying on the bath surface. Unless an extremely large amount of gas is supplied, an appropriate oxide film cannot be formed, and it is difficult to prevent the evaporation of molten zinc.

[0013] Thus, the effect of reducing ash-caused defects by each of the techniques in PTL 1 to PTL 3 is insufficient. Moreover, our study revealed that, in the case where the oxide film is excessively thick, the oxide film adheres to the steel strip surface when the steel strip enters the molten zinc bath, and causes quality defects such as non-coating portions. Quality defects such as non-coating portions caused by the oxide film on the molten zinc bath surface in the snout are hereafter referred to as “oxide film-caused defects”.

[0014] The techniques in PTL 1 to PTL 3 also have the following problem. The suitable oxidizability of the atmosphere in the snout (especially near the bath surface) varies depending on an operation condition such as the chemical composition of the steel strip, the annealing condition in the annealing, or the component of the molten metal bath. Accordingly, when the operation condition is switched over, the oxidizability of the atmosphere in the snout needs to be

changed promptly. With the techniques in PTL 1 to PTL 3, however, the oxidizability of the atmosphere in the snout cannot be changed stably and promptly. Particularly in PTL 3, the presence of large natural convection in the snout makes it impossible to stably and promptly change the oxidizability of the atmosphere in the snout.

[0015] These problems are not limited to hot-dip galvanizing, but apply to hot-dip metal coating in general.

[0016] It could be helpful to provide a continuous hot-dip metal coating method and continuous hot-dip metal coating line that can reduce both non-coating caused by metal vapor generated in a snout and non-coating caused by an oxide film on a molten metal bath surface in the snout and stably and promptly change the oxidizability of the atmosphere in the snout.

Solution to Problem

[0017] As a result of careful examination, we discovered the following.

[0018] (A) To reduce ash-caused defects by suppressing the evaporation of molten zinc (the generation of zinc vapor), an oxide film with at least a predetermined thickness needs to be formed on the bath surface. To reduce oxide film-caused defects, on the other hand, the oxide film thickness needs to be limited to a predetermined thickness or less. This means an oxide film with an optimum thickness needs to be formed in order to reduce both ash-caused defects and oxide film-caused defects.

[0019] (B) To form an oxide film with an optimum thickness, there is a need to precisely manage the dew point of the atmosphere near the molten zinc bath surface in the snout by, while suppressing the convection of the atmosphere in the snout, supplying oxidizing gas into the snout. The best way to achieve this is to supply minimum necessary oxidizing gas into the snout in a state where the heat convection of the atmosphere in the snout is suppressed. This enables oxidizing gas supplied near the bath surface to substantially stay near the bath surface.

[0020] (C) Consequently, the oxidizability of the atmosphere in the snout can be changed stably and promptly. Hence, when the operation condition is switched over or changed, the oxidizability of the atmosphere in the snout can be promptly changed according to the changed operation condition.

[0021] The disclosure is based on these discoveries. We thus provide:

[0022] (1) A continuous hot-dip metal coating method comprising: continuously annealing a steel strip in an annealing furnace; and continuously supplying the steel strip after the annealing into a coating tank containing a bath of molten metal, to metal-coat the steel strip, wherein while the steel strip traveling from the annealing furnace to the molten metal bath passes through a space defined by a snout that is located on a steel strip delivery side of the annealing furnace and has an end immersed in the molten metal bath, oxidizing gas is supplied into the snout, a temperature of an inner wall surface of the snout is maintained at 150° C. or less below a temperature of the molten metal bath, and an atmospheric temperature of an upper portion in the snout is maintained at 100° C. or less below the temperature of the molten metal bath.

[0023] (2) The continuous hot-dip metal coating method according to (1), wherein the oxidizing gas comprises any

one of nitrogen gas containing water vapor and nitrogen-hydrogen mixed gas containing water vapor.

[0024] (3) The continuous hot-dip metal coating method according to (1), wherein oxidizability of the oxidizing gas is changed depending on an operation condition.

[0025] (4) The continuous hot-dip metal coating method according to (2), wherein an amount of the water vapor in the oxidizing gas is changed depending on an operation condition.

[0026] (5) The continuous hot-dip metal coating method according to (2), further comprising preliminarily investigating, for each operation condition, a relationship between a dew point in the snout and an amount of a defect caused by non-coating of the steel strip metal-coated under the operation condition, to determine a target dew point in the snout under the operation condition, wherein an amount of the water vapor in the oxidizing gas is determined based on the target dew point determined for the each operation condition.

[0027] (6) The continuous hot-dip metal coating method according to (5), wherein when the operation condition is switched over, the amount of the water vapor in the oxidizing gas is changed based on the target dew point corresponding to the changed operation condition.

[0028] (7) The continuous hot-dip metal coating method according to any one of (3) to (6), wherein the operation condition is at least one of a chemical composition of the steel strip, an annealing condition in the annealing, and a component of the molten metal bath.

[0029] (8) The continuous hot-dip metal coating method according to any one of (3) to (6), wherein the operation condition is a chemical composition of the steel strip.

[0030] (9) The continuous hot-dip metal coating method according to any one of (1) to (8), wherein the oxidizing gas is supplied from both edges of the snout in a transverse direction of the steel strip.

[0031] (10) A continuous hot-dip metal coating line comprising: an annealing furnace that continuously anneals a steel strip; a coating tank containing a bath of molten metal; a snout located on a steel strip delivery side of the annealing furnace, having an end immersed in the molten metal bath, and defining a space through which the steel strip continuously supplied from the annealing furnace into the molten metal bath passes; a heating unit provided on an outer wall of the snout and in an upper portion in the snout; a gas supply mechanism connected to the snout; and a controller that controls the heating unit and the gas supply mechanism to supply oxidizing gas into the snout, maintain a temperature of an inner wall surface of the snout as 150° C. or less below a temperature of the molten metal bath, and maintain an atmospheric temperature of an upper portion in the snout at 100° C. or less below the temperature of the molten metal bath.

Advantageous Effect

[0032] It is possible to provide a continuous hot-dip metal coating method and continuous hot-dip metal coating line that can reduce both non-coating caused by metal vapor generated in a snout and non-coating caused by an oxide film on a molten metal bath surface in the snout and stably and promptly change the oxidizability of the atmosphere in the snout.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] In the accompanying drawings:

[0034] FIG. 1 is a schematic view of a continuous hot-dip galvanizing line 100 according to one of the disclosed embodiments;

[0035] FIG. 2 is a view illustrating half of the inside of a snout 14 in FIG. 1 from the transverse center of a steel strip P;

[0036] FIG. 3 is an enlarged schematic view of the snout 14 in FIG. 1;

[0037] FIG. 4 is a graph illustrating the relationship between the oxidizability of the bath surface atmosphere and the defect rate;

[0038] FIG. 5A is a graph illustrating the relationship between the oxidizability of the bath surface atmosphere and the defect rate for high Si-containing steel and low Si-containing steel;

[0039] FIG. 5B is a graph illustrating the relationship between the oxidizability of the bath surface atmosphere and the oxide film thickness for a high Al-containing bath and a low Al-containing bath;

[0040] FIG. 6A is a graph illustrating the relationship between the dew point in the snout and the defect rate for steel type A;

[0041] FIG. 6B is a graph illustrating the relationship between the dew point in the snout and the defect rate for steel type B; and

[0042] FIG. 7 is a graph illustrating the change of the dew point in the snout in each of Examples 1 to 3 and Comparative Examples 1 and 2.

DETAILED DESCRIPTION

[0043] A continuous hot-dip galvanizing line 100 and a continuous hot-dip galvanizing method using the continuous hot-dip galvanizing line 100 according to one of the disclosed embodiments are described below.

[0044] In FIG. 1, the continuous hot-dip galvanizing line 100 includes an annealing furnace 10, a coating tank 12, and a snout 14.

[0045] The annealing furnace 10 is a device that continuously anneals a steel strip P passing through the annealing furnace 10, and includes a heating zone, a soaking zone, and a cooling zone arranged side by side in this order. Only the cooling zone is illustrated in FIG. 1. The annealing furnace may have a well-known structure or any structure. Reducing gas or non-oxidizing gas is typically supplied into the annealing furnace. As the reducing gas, H_2 — N_2 mixed gas is typically used. An example of such gas is gas (dew point: about $-60^\circ C.$) having a composition containing H_2 : 1 vol % to 20 vol % with the balance being N_2 and incidental impurities. An example of the non-oxidizing gas is gas (dew point: about $-60^\circ C.$) having a composition containing N_2 and incidental impurities. The annealed steel strip P is cooled to about $470^\circ C.$ to $500^\circ C.$ in the cooling zone.

[0046] The coating tank 12 contains a molten zinc bath 12A. The snout 14 is located on the steel strip delivery side of the annealing furnace 10. The snout 14 is connected to the cooling zone in this embodiment. A snout end 14A is immersed in the molten zinc bath 12A. The snout 14 is a member that defines the space through which the steel strip P continuously supplied from the annealing furnace 10 into the molten zinc bath 12A passes. A turn-down roll 26 for changing the traveling direction of the steel strip P from

horizontal to obliquely downward is located in an upper portion in the snout 14. The part of the snout 14 that defines the space through which the steel strip P having passed through the turn-down roll 26 passes is rectangular in section perpendicular to the traveling direction of the steel strip P.

[0047] The steel strip P passes through the inside of the snout 14, and continuously enters the molten zinc bath 12A. A sink roll 28 and support rolls 30 are installed in the molten zinc bath 12A. Having entered the molten zinc bath 12A, the steel strip P is changed upward in the sheet passing direction by the sink roll 28, and then guided by the support rolls 30 to leave the molten zinc bath 12A. The steel strip P is thus hot-dip galvanized.

[0048] In FIG. 2, the continuous hot-dip galvanizing line 100 includes a gas supply mechanism 20 connected to the snout 14. The gas supply mechanism 20 includes: a first pipe 22A through which hydrogen gas passes; a second pipe 22B through which nitrogen gas passes; a third pipe 22C through which water vapor as oxidizing gas passes; flow rate adjusting valves 24 attached to these pipes; a fourth pipe 22D through which mixed gas obtained by mixing the gases supplied from these pipes passes; and a fifth pipe 22E connected to the fourth pipe 22D and has its tip located inside the snout 14. The first pipe 22A and the third pipe 22C are connected to the second pipe 22B. By regulating the valves 24, hydrogen, nitrogen, and water vapor can be mixed at any flow ratio.

[0049] The oxidizing gas is not limited, and may be gas containing water vapor, oxygen, carbon dioxide, or the like. Gas containing water vapor is preferable because its oxidizability is not excessively high and so it is easy to be managed, is inexpensive, and is easy to be measured in oxidizability by a dew point meter.

[0050] In FIG. 3, a heater 16 as a heating unit is placed on the outer wall of the snout 14, and covered with a heat insulator 18. The heater 16 covers the whole outer wall except the tip portion of the snout 14 (near the bath surface). A heater 17 as a heating unit is also placed in the upper portion in the snout. Since the upper portion in the snout has significant influence on the occurrence of heat convection as described later, providing the heater 17 ensures that the atmospheric temperature of the upper portion in the snout is increased.

[0051] In this embodiment, it is important that a controller (not illustrated) controls the heaters 16 and 17 and the gas supply mechanism 20 to supply the oxidizing gas into the snout 14 and maintain the temperature of the inner wall surface of the snout 14 at (a temperature of the molten metal bath— $150^\circ C.$) or more and the atmospheric temperature of the upper portion in the snout 14 at (the temperature of the molten metal bath— $100^\circ C.$) or more. The technical significance of this control is described below.

[0052] As mentioned earlier, there is an optimum level for the oxidizability of the atmosphere in the snout. FIG. 4 illustrates the concept of such an optimum level. In the case where the oxidizability is low, no oxide film forms on the bath surface or, even when an oxide film forms, the oxide film is very thin. In this case, oxide film-caused defects are unlikely to occur, but zinc evaporates actively and so ash-caused defects increase. In the case where the oxidizability is high, a thick oxide film serves as a protective film and zinc hardly evaporates. In this case, ash-caused defects are unlikely to occur, but oxide film-caused defects occur a lot.

[0053] It is therefore necessary to precisely control the oxidizability of the atmosphere near the bath surface where zinc evaporates or oxidizes, to the optimum level (the center part in FIG. 4). We discovered that, for example in the case of controlling the oxidizability of the atmosphere near the bath surface by supplying gas containing water vapor into the snout, both ash-caused defects and oxide film-caused defects can be reduced to low level by precisely controlling the dew point of the atmosphere near the bath surface within the range of about a predetermined point (target dew point) $\pm 4^{\circ}\text{C}$. The target dew point can be determined by the below-mentioned method once the operation conditions other than the target dew point are determined.

[0054] Here, the convection of the atmosphere in the snout makes it difficult to manage the dew point near the bath surface. Main convection in the snout includes an accompanying flow that occurs due to the movement of the steel strip, a heat convection flow associated with the temperature difference in the snout, and a pressure flow caused by the pressure difference in the snout. Under a normal snout condition, the influence of heat convection flow is dominant. For example, in the case where the steel strip temperature is 500°C . and the temperature of the molten metal bath is 450°C ., the temperature difference of the inside of the snout from the outside of the snout is 400°C . or more. Moreover, since the upper portion in the snout is usually connected to the cooling zone, the atmospheric temperature of the upper portion in the snout tends to be 200°C . to 300°C . In such a case, the wind velocity by heat convection is about 4 m/s to 5 m/s, which is considerably higher than a typical value of a steel strip accompanying flow of 1 m/s.

[0055] Even when gas facilitating bath surface oxidation, such as gas containing water vapor, is supplied in this situation, most of the gas does not stay on the bath surface. To form an oxide film with an appropriate thickness for reducing ash-caused defects, a large amount of water vapor needs to be supplied. Meanwhile, to reduce oxide film-caused defects, the concentration distribution of the oxidizing gas near the bath surface needs to be minimized because a thinner oxide film is more advantageous. Under a large heat convection condition, however, the concentration distribution of the oxidizing gas near the bath surface is high (i.e. the concentration is not uniform within the surface), so that managing the dew point near the bath surface is extremely difficult.

[0056] Based on the aforementioned discoveries, we concluded that the most effective way of precisely managing the dew point near the bath surface to reduce both ash-caused defects and oxide film-caused defects is to suppress zinc evaporation, and the best way of suppressing zinc evaporation is to supply minimum necessary oxidizing gas into the snout while suppressing heat convection in the snout.

[0057] We then aimed to reduce the temperature difference in the snout which causes such heat convection. Although the steel strip is highest in temperature in the snout, the steel strip temperature is normally higher than the bath temperature only by about 10°C . Hence, the temperature of the molten metal bath is used as the reference temperature in the disclosure. Since the heat convection flow and the steel strip accompanying flow are in opposite directions, the convection in the snout is greatly reduced if the magnitude of the heat convection flow can be limited to not more than twice the magnitude of the steel strip accompanying flow.

[0058] As a result of careful examination, we discovered that, by maintaining the temperature of the inner wall surface of the snout at (the temperature of the molten metal bath -150°C .) or more, the convection of the atmosphere in the snout can be reduced to such a flow state where the influence of temperature is negligible. Here, the atmospheric temperature of the upper portion in the snout has more influence on heat convection, and so needs to be maintained at (the temperature of the molten metal bath -100°C .) or more. This is because a density flow has higher flow velocity in the case where gas having high density is present at a high position. (A flow caused by density is proportional to $\Delta\rho gh$ where h is the height difference. The presence of a high density substance at a high position increases flow velocity.)

[0059] The atmospheric temperature of the upper portion in the snout is preferably (the temperature of the molten metal bath $+100^{\circ}\text{C}$.) or less. Although the convection in the snout is more stabilized when the atmospheric temperature of the upper portion is higher (the presence of a low density substance in the upper portion contributes to a stable state), the stabilizing effect is saturated if the atmospheric temperature of the upper portion is more than (the temperature of the molten metal bath $+100^{\circ}\text{C}$.). The temperature of the inner wall surface of the snout is preferably (the temperature of the molten metal bath $+0^{\circ}\text{C}$.) or less. If the temperature of the inner wall surface is higher than the temperature of the molten metal bath, an upward flow occurs near the side wall in the snout, as a result of which a downward flow occurs in the center portion. Since this flow is in the same direction as the steel strip accompanying flow, a large flow will result in the snout. Thus, there is no need to maintain the temperature of the inner wall surface at higher than the temperature of the molten metal bath, and rather such temperature control is likely to cause a larger flow.

[0060] The term “upper portion in the snout” in the disclosure means the region in the snout within 1 m from the surface of the turndown roll. In FIG. 3, the upper portion in the snout is the region within 1 m from the surface of the turndown roll 26 in the snout 14.

[0061] By supplying the oxidizing gas into the snout in a state where the temperature of the inner wall surface of the snout and the atmospheric temperature of the upper portion in the snout are managed in this way, most of the oxidizing gas reaching near the bath surface can stay on the bath surface, so that the generation of zinc vapor can be suppressed with a smaller amount of gas. Moreover, since the gas component supplied into the snout is present near the bath surface with substantially no change, the atmosphere can be controlled easily, with it being possible to reduce the variation of the dew point of the atmosphere near the bath surface. Consequently, oxide film-caused defects can be reduced, too. Thus, the oxidation state of the bath surface in the snout can be maintained ideally, so that both ash-caused defects and oxide film-caused defects can be almost eliminated. Further, the oxidizability of the atmosphere in the snout can be changed stably and promptly. Hence, when an operation condition is switched over, the oxidizability of the atmosphere in the snout can be promptly changed according to the changed operation condition.

[0062] The oxidizing gas supplied into the snout is preferably nitrogen gas containing water vapor or nitrogen-hydrogen mixed gas containing water vapor. The dew point of the oxidizing gas may be set as appropriate depending on the composition of the molten bath, the steel type to be

manufactured, and other operation conditions, but tends to be favorable in the range of about -20°C . to -35°C . Although the oxidizing gas supply amount depends on various operation conditions, in the case where the conditions other than the temperature of the inner wall surface of the snout and the atmospheric temperature of the upper portion in the snout are the same, the same dew point can be achieved with a supply amount of about $\frac{1}{4}$ as compared with when the temperature of the inner wall surface and the atmospheric temperature of the upper portion are outside the ranges according to the disclosure. The oxidizing gas supply amount can thus be reduced to the minimum necessary amount for forming an appropriate oxide film.

[0063] As illustrated in FIG. 2, the oxidizing gas is preferably supplied into the snout 14 from both edges of the snout in the steel strip transverse (width) direction. The reason why the fifth pipe 22E having a gas supply port is located on the side surface of the snout 12 is that, since the temperature near the side surface in the snout tends to be low and so a downward flow usually occurs near the side surface, the oxidizing gas can be efficiently delivered to near the bath surface. The height of the gas supply port from the bath surface may be about 100 mm to 3000 mm. If the height is less than 100 mm, the gas is highly likely to directly reach the bath surface, causing an increase in concentration distribution of the oxidizing gas near the bath surface. If the height is more than 3000 mm, the gas concentration decreases due to a long distance from the bath surface, so that a large amount of gas is needed.

[0064] The suitable oxidizability of the atmosphere near the bath surface in the snout varies depending on an operation condition such as the chemical composition of the steel strip, the annealing condition in the annealing, or the component of the molten zinc bath. In other words, the two curves illustrated in FIG. 4 can shift right or left depending on the operation condition. This is described below, with reference to FIGS. 5A and 5B as an example.

[0065] Both ash-caused defects and oxide film-caused defects correlate to the thickness of the oxide film formed on the bath surface, as mentioned above. In detail, ash-caused defects relate to the amount of ash and its adhesion rate, and oxide film-caused defects relate to the amount of oxide film and its adhesion rate.

[0066] FIG. 5A illustrates an example of the influence of the chemical composition of the steel strip on the suitable oxidizability of the atmosphere near the bath surface in the snout. In the case where the steel strip contains a lot of oxidizable element such as Si, Mn, or Al, a large amount of oxide is concentrated on the surface of the steel strip immediately before entering the molten bath. If the steel strip is coated in such a surface concentration state, the oxide film easily adheres to the steel strip, that is, the adhesion rate of the oxide film is high, facilitating oxide film-caused defects. On the other hand, the amount of ash hardly depends on the surface concentration state of the steel strip, and so the chemical composition of the steel strip hardly influences ash-caused defects.

[0067] The surface concentration state of the steel strip also differs depending on the annealing condition such as the annealing temperature and the furnace dew point. Thus, the annealing condition also influences oxide film-caused defects, but hardly influences ash-caused defects.

[0068] FIG. 5B illustrates an example of the influence of the component of the molten zinc bath on the suitable

oxidizability of the atmosphere near the bath surface in the snout. As illustrated in FIG. 5B, when the Al concentration in the bath is higher, an oxide film forms on the bath surface more easily. Thus, a high Al-containing bath causes fewer ash-caused defects, and more oxide film-caused defects. In other words, the two curves in FIG. 4 shift to the left.

[0069] It is therefore preferable to change the oxidizability of the oxidizing gas depending on the operation condition. In detail, in the case where the oxidizing gas contains water vapor, the amount of water vapor in the oxidizing gas is changed depending on the operation condition, as the suitable dew point of the atmosphere near the bath surface, i.e. the target dew point, differs depending on the operation condition. The amount of water vapor in the oxidizing gas is typically 100 ppm or more.

[0070] In this case, for each operation condition, the relationship between the dew point in the snout and the defect rates of ash-caused defects and oxide film-caused defects (i.e. the information in FIG. 4) may be preliminarily investigated to determine the target dew point in the snout under the operation condition. The amount of water vapor in the oxidizing gas may then be determined based on the target dew point determined for the operation condition. When the operation condition is switched over, the amount of water vapor in the oxidizing gas may be changed based on the target dew point corresponding to the changed operation condition.

[0071] The relationship between the dew point in the snout and the defect rates of ash-caused defects and oxide film-caused defects as illustrated in FIG. 4 can be determined by preliminarily recognizing the tendency of the correspondence between the dew point in the snout and the defect rate of each type of defect in past operation. Whether or not each type of defect occurs may be visually determined. The size of a visually observable defect is about 100 μm or more. The rate of defect occurrence per 0.5 m in length is defined as "defect rate". A defect rate of 1% means one defect per 50 m.

[0072] The aforementioned dew point in the snout needs to be the dew point immediately above the bath surface (near the bath surface). In the case where the actual dew point measurement location is not immediately above the bath surface, the following adjustment is performed. In a state where heat convection in the snout is eliminated according to the disclosure, there is hardly any dew point distribution in the snout, and so the actual measured dew point can be directly used as the dew point in the snout. If there is heat convection in the snout, however, the actual measured dew point is corrected to the dew point near the bath surface. This correction can be performed using the dew point distribution predicted from flow analysis. For example, in the case where the dew point at a height of 500 mm from the bath surface is -35°C . and the dew point near the bath surface is -30°C . according to flow analysis, the difference in dew point is $+5^{\circ}\text{C}$., and the difference in water ratio is 150 ppm. Accordingly, the dew point obtained by adding the value corresponding to 150 ppm to the actual measured dew point value at a height of 500 mm can be used as the bath surface dew point.

[0073] Examples of the operation condition influencing the suitable oxidizability of the atmosphere near the bath surface in the snout (the target dew point of the atmosphere near the bath surface in the case where the oxidizing gas contains water vapor) include the steel type (the chemical

composition of the steel strip), the annealing condition in the annealing, and the component of the molten zinc bath. At least one of these operation conditions is preferably used to obtain the information in FIG. 4 beforehand. For example, in the case where it is known that the annealing condition and the component of the molten zinc bath are fixed in a specific continuous hot-dip galvanizing line, the information in FIG. 4 is preliminarily investigated for each steel type scheduled to pass through the line, to determine the target dew point. When the steel type is switched over, the amount of water vapor in the oxidizing gas is changed so that the target dew point corresponds to the changed steel type.

[0074] The disclosure is not limited to the foregoing embodiment, and equally applies to the case of continuously hot-dip metal coating a steel strip.

EXAMPLES

First Example

[0075] Using the continuous hot-dip galvanizing line in FIGS. 1 to 3, each steel strip (hereafter referred to as “steel type A”) having a chemical composition containing, in mass %, C: 0.001%, Si: 0.01%, Mn: 0.1%, P: 0.003%, S: 0.005%, and Al: 0.03% with the balance being Fe and incidental impurities and having a sheet thickness of 0.6 mm to 1.2 mm, a sheet width of 900 mm to 1250 mm, and a tensile strength of 270 MPa was entered into the molten zinc bath at a sheet passing speed of 60 mpm to 100 mpm, to manufacture a hot-dip galvanized steel sheet. The fifth pipe having a gas supply port was located on the side surface of the snout, and the height of the gas supply port from the bath surface was 500 mm, as illustrated in FIG. 2. The relationship between the dew point in the snout and the defect rates of ash-caused defects and oxide film-caused defects was preliminarily investigated from past operation data. FIG. 6A illustrates the results. Based on FIG. 6A, the target dew point in the snout was determined to be -30°C . This indicates that both ash-caused defects and oxide film-caused defects are reduced to low level if the dew point in the snout can be controlled within the range of about $-30^{\circ}\text{C} \pm 4^{\circ}\text{C}$.

[0076] While the steel strip passed through the snout, nitrogen-hydrogen mixed gas containing water vapor was supplied from the gas supply port in test examples No. 1 to 5 (“water vapor: supplied” in Table 1), and nitrogen-hydrogen mixed gas not containing water vapor was supplied from the gas supply port in test examples No. 6 and 7 (“water vapor: not supplied” in Table 1). The dew point of the supplied gas in test examples No. 1 to 5 was measured by a dew point meter provided in a dew point measurement hole 32A in the fifth pipe in FIG. 2, and is listed in Table 1.

[0077] The temperature of the snout inner wall surface and the atmospheric temperature of the upper portion in the snout while the steel strip passed through the snout were managed as listed in Table 1. In test example No. 6, no heating by the heaters provided on the snout outer wall and in the upper portion in the snout was performed.

[0078] In each test example, the dew point of the atmosphere in the snout was measured over time, by a dew point meter provided in a dew point measurement hole 32B at a height of 500 mm in the center portion of the back of the snout in FIG. 2. In each of test examples No. 1 to 7, based on the difference between the measured dew point and the target dew point (-30°C), the flow rate of the supplied gas was changed so that the measured dew point was closer to

the target dew point. This control was performed by typical PID control logic. A histogram of the measured dew point in each of test examples No. 1 to 7 is listed in Table 2. For each of test examples No. 1 to 5, the proportion of the volume of water vapor to the total volume of the supplied gas in the test is indicated as “water amount” in Table 1, and the total gas supply flow rate in the test is indicated as an index in Table 1 with the total flow rate of No. 5 being set to 1.

[0079] Given that the dew point to be managed is the dew point immediately above the bath surface, the dew point meter needs to be at a lower position near the bath surface. According to the disclosure, however, there is hardly any dew point distribution in the snout, so that the dew point near the bath surface can be accurately determined even when the dew point measurement is performed at a height of 500 mm. In Comparative Examples with the generation of zinc vapor, the dew point meter cannot be installed in the lower portion of the snout due to the risk of zinc vapor adhering to the sensor part of the dew point meter if the dew point meter is at a low position such as a height of about 100 mm from the bath surface. While the gas measuring instrument was the dew point meter in this example as water vapor was used in the oxidizing gas, in the case of using oxidizing gas other than water vapor, a measuring instrument for detecting such gas needs to be installed.

[0080] (Evaluation of Defect Rate)

[0081] The defect rate of each of ash-caused defects and oxide film-caused defects was evaluated by the following method. Whether or not each type of defect occurred was visually determined. The size of a visually observable defect is about 100 μm or more. The rate of defect occurrence per 0.5 m in length is defined as “defect rate”, and listed in Table 1. A defect rate of 1% means one defect per 50 m.

[0082] (Evaluation Results)

[0083] The evaluation results are described below, with reference to Tables 1 and 2. No. 1 (Example) is an example with no temperature difference among the bath temperature, the wall surface temperature, and the upper portion temperature. There was little variation in dew point, and as a result ash-caused defects and oxide film-caused defects hardly occurred. No. 2 (Example) is an example with a low wall surface temperature, and No. 3 (Example) is an example with a low atmospheric temperature of the snout upper portion. In these examples, the dew point of the atmosphere in the snout was able to be controlled within the management range ($-30^{\circ}\text{C} \pm 4^{\circ}\text{C}$), as a result of which each defect rate was kept at low level. Moreover, in No. 1 to 3, the gas supply flow rate was sufficiently reduced as compared with No. 5.

[0084] No. 4 (Comparative Example) is an example with the wall surface temperature being outside the range according to the disclosure, and No. 5 (Comparative Example) is an example with the atmospheric temperature of the snout upper portion being outside the range according to the disclosure. In these examples, the dew point of the atmosphere in the snout was unable to be controlled within the management range ($-30^{\circ}\text{C} \pm 4^{\circ}\text{C}$), as a result of which many ash-caused defects or oxide film-caused defects occurred. No. 6 (Comparative Example) is an example without water vapor supply and without heating by the heaters. In this case, the dew point was low around -40°C , and so oxide film-caused defects did not occur, but a large number of ash-caused defects occurred. In No. 7 (Comparative Example), the dew point was stable because there was no temperature difference, but was low around -40°C , so that a large number of ash-caused defects occurred.

TABLE 1

No.	Water vapor	Bath	Wall surface	Upper portion	Supply dew	Water	Supply flow	Defect rate (%)		Category
		temperature (° C.)	temperature (° C.)	temperature (° C.)	point (° C.)	amount (ppm)	rate (Nm ³ /hr)	Ash-caused defect	Oxide film- caused defect	
1	Supplied	450	450	450	-29	415	0.31	0.02	0.00	Example 1
2	Supplied	450	300	450	-28	460	0.29	0.06	0.03	Example 2
3	Supplied	450	450	350	-28	460	0.36	0.05	0.03	Example 3
4	Supplied	450	250	450	-20	1015	0.70	0.13	1.06	Comparative Example 1
5	Supplied	450	450	300	-25	622	1	1.22	0.28	Comparative Example 2
6	Not supplied	450	250	200	—	—	—	5.68	0.00	Comparative Example 3
7	Not supplied	450	450	450	—	—	—	5.13	0.00	Comparative Example 4

TABLE 2

Measured dew point (° C.)	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
to -20				1.1%			
-20 to -22				2.8%			
-22 to -24				6.7%			
-24 to -26				12.3%	3.0%		
-26 to -28	3.2%	11.2%	12.3%	17.3%	12.6%		
-28 to -30	49.6%	35.8%	40.0%	21.6%	21.8%		
-30 to -32	44.3%	39.3%	37.1%	23.3%	20.6%		
-32 to -34	2.9%	13.7%	10.6%	11.5%	18.6%		
-34 to -36				3.4%	12.5%	2.3%	
-36 to -38					6.8%	3.6%	
-38 to -40					3.3%	43.6%	63.8%
from -40					0.8%	50.5%	36.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Category	Example	Example	Example	Comparative Example	Comparative Example	Comparative Example	Comparative Example

Second Example

[0085] The relationship between the dew point in the snout and the defect rates of ash-caused defects and oxide film-caused defects was determined in the same way as in the first example, except that, instead of the steel strip of steel type A, each steel strip (hereafter referred to as “steel type B”) having a chemical composition containing, in mass %, C: 0.12%, Si: 1.0%, Mn: 1.7%, P: 0.006%, S: 0.006%, and Al: 0.03% with the balance being Fe and incidental impurities and having a sheet thickness of 0.6 mm to 1.2 mm, a sheet width of 900 mm to 1250 mm, and a tensile strength of 780 MPa was used. FIG. 6B illustrates the results.

[0086] As illustrated in FIGS. 6A and 6B, for both steel types A and B, there is a dew point at which both ash-caused defects and oxide film-caused defects can be sufficiently reduced. In steel type B, however, the optimum value, i.e. the target dew point, is lower, and the dew point range in which both defect rates are sufficiently low is narrower. This indicates that, for example when switching from steel type A to steel type B, the dew point of the atmosphere needs to be changed accurately in a short time.

Third Example

[0087] The speed of changing the dew point of nitrogen-hydrogen mixed gas containing water vapor was examined, in a state of the bath temperature, the wall surface temperature, and the upper portion temperature in No. 1 to 5

(Examples 1 to 3 and Comparative Examples 1 and 2) in Table 1. As illustrated in FIG. 7, the supply dew point was changed from -35° C. to -20° C. at 50 minutes.

[0088] In Example 1, the bath temperature, the wall surface temperature, and the upper portion temperature were all set to 450° C., and so there was hardly any heat convection. Accordingly, the measured dew point changed substantially in the same way as the change of the dew point of the supplied gas. The dew point in the snout can thus be directly controlled using the dew point of the supplied gas, which is very advantageous in terms of quality management. In Examples 2 and 3, the changed dew point had some delay as compared with Example 1, but was able to follow the supply dew point after about 30 minutes, which is sufficient in terms of quality management.

[0089] In Comparative Examples 1 and 2, after the supply dew point was changed, the dew point in the snout continued to increase gradually while varying, and was far from being stable even after 1 hour. In such a state, it is difficult to respond to the change of the target dew point when, for example, switching from steel type A to steel type B.

INDUSTRIAL APPLICABILITY

[0090] The disclosed continuous hot-dip metal coating method and continuous hot-dip metal coating line can reduce both non-coating caused by metal vapor generated in

a snout and non-coating caused by an oxide film on a molten metal bath surface in the snout.

REFERENCE SIGNS LIST

- [0091] 100 continuous hot-dip galvanizing line
- [0092] 10 annealing furnace
- [0093] 12 coating tank
- [0094] 12A molten zinc bath
- [0095] 14 snout
- [0096] 14A snout end
- [0097] 16, 17 heater
- [0098] 18 heat insulator
- [0099] 20 gas supply mechanism
- [0100] 22A, 22B, 22C, 22D, 22E pipe
- [0101] 24 valve
- [0102] 26 turndown roll
- [0103] 28 sink roll
- [0104] 30 support roll
- [0105] 32A, 32B dew point measurement hole
- [0106] P steel strip

1. A continuous hot-dip metal coating method comprising: continuously annealing a steel strip in an annealing furnace; and continuously supplying the steel strip after the annealing into a coating tank containing a bath of molten metal, to metal-coat the steel strip, wherein while the steel strip traveling from the annealing furnace to the molten metal bath passes through a space defined by a snout that is located on a steel strip delivery side of the annealing furnace and has an end immersed in the molten metal bath, oxidizing gas is supplied into the snout, a temperature of an inner wall surface of the snout is maintained at 150° C. or less below a temperature of the molten metal bath, and an atmospheric temperature of an upper portion in the snout is maintained at 100° C. or less below the temperature of the molten metal bath.
2. The continuous hot-dip metal coating method according to claim 1, wherein the oxidizing gas comprises any one of nitrogen gas containing water vapor and nitrogen-hydrogen mixed gas containing water vapor.
3. The continuous hot-dip metal coating method according to claim 1, wherein oxidizability of the oxidizing gas is changed depending on an operation condition.
4. The continuous hot-dip metal coating method according to claim 2, wherein an amount of the water vapor in the oxidizing gas is changed depending on an operation condition.
5. The continuous hot-dip metal coating method according to claim 2, further comprising preliminarily investigating, for each operation condition, a relationship between a dew point in the snout and an amount of a defect caused by non-coating of the steel strip metal-coated under the operation condition, to determine a target dew point in the snout under the operation condition,

wherein an amount of the water vapor in the oxidizing gas is determined based on the target dew point determined for the each operation condition.

6. The continuous hot-dip metal coating method according to claim 5, wherein when the operation condition is switched over, the amount of the water vapor in the oxidizing gas is changed based on the target dew point corresponding to the changed operation condition.
7. The continuous hot-dip metal coating method according to claim 3, wherein the operation condition is at least one of a chemical composition of the steel strip, an annealing condition in the annealing, and a component of the molten metal bath.
8. The continuous hot-dip metal coating method according to claim 3, wherein the operation condition is a chemical composition of the steel strip.
9. The continuous hot-dip metal coating method according to claim 1, wherein the oxidizing gas is supplied from both edges of the snout in a transverse direction of the steel strip.
10. A continuous hot-dip metal coating line comprising: an annealing furnace that continuously anneals a steel strip; a coating tank containing a bath of molten metal; a snout located on a steel strip delivery side of the annealing furnace, having an end immersed in the molten metal bath, and defining a space through which the steel strip continuously supplied from the annealing furnace into the molten metal bath passes; a heating unit provided on an outer wall of the snout and in an upper portion in the snout; a gas supply mechanism connected to the snout; and a controller that controls the heating unit and the gas supply mechanism to supply oxidizing gas into the snout, maintain a temperature of an inner wall surface of the snout as 150° C. or less below a temperature of the molten metal bath, and maintain an atmospheric temperature of an upper portion in the snout at 100° C. or less below the temperature of the molten metal bath.
11. The continuous hot-dip metal coating method according to claim 4, wherein the operation condition is at least one of a chemical composition of the steel strip, an annealing condition in the annealing, and a component of the molten metal bath.
12. The continuous hot-dip metal coating method according to claim 5, wherein the operation condition is at least one of a chemical composition of the steel strip, an annealing condition in the annealing, and a component of the molten metal bath.
13. The continuous hot-dip metal coating method according to claim 4, wherein the operation condition is a chemical composition of the steel strip.
14. The continuous hot-dip metal coating method according to claim 5, wherein the operation condition is a chemical composition of the steel strip.

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