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(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

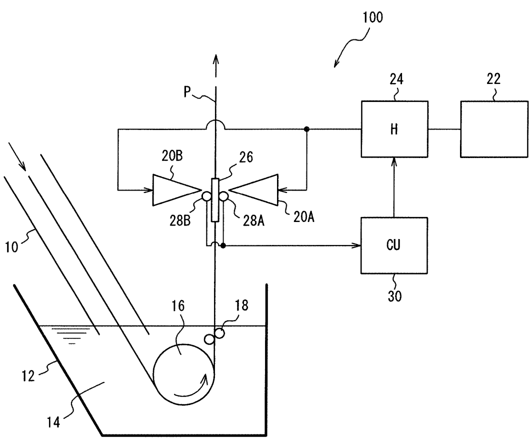
(72) Inventors:
- **TERASAKI, Yu**
  Tokyo 100-0011 (JP)
- **TAKAHASHI, Hideyuki**
  Tokyo 100-0011 (JP)
- **MIYAKE, Masaru**
  Tokyo 100-0011 (JP)
- **KOYAMA, Takumi**
  Tokyo 100-0011 (JP)
- **YASUFUKU, Yusuke**
  Tokyo 100-0011 (JP)
- **INABA, Atsushi**
  Tokyo 100-0011 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) PRODUCTION APPARATUS AND PRODUCTION METHOD FOR MOLTEN METAL PLATED STEEL STRIP

(57) An apparatus for producing a hot-dip metal coated steel strip by which a hot-dip metal coated steel strip of high quality can be stably produced by preventing coated surface defects caused by splashing or top dross even in the case where operation conditions vary is provided. An apparatus 100 for producing a hot-dip metal coated steel strip includes: a pair of gas wiping nozzles 20A and 20B that adjust a coating weight on both surfaces of a steel strip P; a gas supply mechanism 22; a gas temperature adjusting mechanism 24; a baffle plate 26 located near a transverse edge of the steel strip P and in a plane extended from the steel strip; a temperature sensor 28 located on at least one surface of the baffle plate 26; and a controller 30 that controls the gas temperature adjusting mechanism 24 based on an output of the temperature sensor 28.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The disclosure relates to an apparatus and a method for producing a hot-dip metal coated steel strip, and particularly relates to gas wiping for adjusting the coating weight on the steel strip surface.

BACKGROUND

[0002] In a continuous hot-dip metal coating line as illustrated in FIG. 4, a steel strip P annealed in a continuous annealing furnace with a reducing atmosphere passes through a snout 10, and is continuously introduced into a molten metal bath 14 in a coating tank 12. The steel strip P is then pulled upward from the molten metal bath 14 through a sink roll 16 and support rolls 18 in the molten metal bath 14, and adjusted to have a predetermined coating thickness by gas wiping nozzles 20A and 20B. After this, the steel strip P is cooled, and guided to subsequent steps. The gas wiping nozzles 20A and 20B face each other with the steel strip P therebetween, above the coating tank 12. The gas wiping nozzles 20A and 20B spray gas onto both surfaces of the steel strip P from their jet orifices. By this gas wiping, excess molten metal is wiped away to adjust the coating weight on the steel strip surface and also uniformize, in the sheet transverse (width) direction and the sheet longitudinal direction, the molten metal adhering to the steel strip surface. The gas wiping nozzles 20A and 20B are each typically made longer than the steel strip width to accommodate various steel strip widths and also cope with, for example, a displacement of the steel strip in the transverse direction when pulling the steel strip up. The gas wiping nozzles 20A and 20B thus each extend outward beyond the transverse edges of the steel strip.

[0003] In such gas wiping, a phenomenon called splashing, that is, molten metal dropping downward and splattering on the steel strip due to the disturbance of the gas jet colliding against the steel strip, occurs. Splashed molten metal adheres to the steel strip surface, and lowers the surface quality of the coated steel strip. The problem of splashing is more apparent when the pressure of the gas (hereafter simply referred to as "gas pressure") sprayed from the gas wiping nozzles onto the steel strip surface is higher. Splashed molten metal also drops into the coating tank and forms top dross. This lowers the surface quality of the coated steel strip, and requires a worker to remove the top dross.

[0004] Production volume in the continuous steel strip production process can be increased by increasing the steel strip passing speed (line speed). In the case of adjusting the coating weight by gas wiping in the continuous hot-dip coating process, however, increasing the line speed increases the initial coating weight of the steel strip immediately after passing through the molten bath due to the viscosity of molten metal, so that higher gas pressure is needed to adjust the coating weight within a predetermined range. As a result, splashing increases significantly.

[0005] Higher gas pressure is also effective in reducing the coating weight. However, splashing increases significantly in this case, too.

[0006] To solve the problem of splashing, techniques of increasing the temperature of the gas sprayed from the gas wiping nozzles onto the steel strip surface to improve the wiping ability have been proposed. JP 2009-203500 A (PTL 1) describes the following hot-dip metal coated steel strip production method. A main nozzle and a pair of sub nozzles above and below the main nozzle are used for gas wiping, where the temperature of gas sprayed from the sub nozzles is 500 °C or less, and is higher than the temperature of gas sprayed from the main nozzle by 50 °C or more. JP 2009-263698 A (PTL 2) describes the following hot-dip coating weight control method. Gas containing combustion gas generated by combustion inside a gas wiping nozzle is sprayed, with the gas temperature at the outlet of the gas wiping nozzle being set to 300 °C or more.

CITATION LIST

Patent Literatures

[0007]

PTL 1 : JP 2009-203500 A
PTL 2: JP 2009-263698 A

SUMMARY

(Technical Problem)

[0008] If the wiping ability is improved by any of the techniques in PTL 1 and PTL 2, there is no need to increase the gas pressure, and so splashing can be reduced. However, PTL 1 and PTL 2 both specify the gas temperature Ty at the outlet of the gas wiping nozzle, which causes the following problem. Gas ejected from the gas wiping nozzle mixes with surrounding air, and gradually decreases in temperature. Therefore, in the case where the distance between the gas wiping nozzle and the steel strip is long, the gas temperature T at the steel strip collision point (stagnation point) decreases to be close to normal temperature, and the effect of heating the gas is lost. The decrease of the gas temperature depends not only on the distance between the nozzle and the steel strip, but also on conditions such as gas pressure and nozzle angle. These operation conditions may vary among products. Hence, even when the gas temperature Ty at the nozzle outlet is set to a predetermined temperature, the gas temperature at the stagnation point differs depending on operation conditions, resulting in different splashing quantity or top dross quantity. Besides, even when the gas temperature Ty at the nozzle outlet is set to a predetermined temperature, it is very difficult to accurately predict the gas temperature T at the stagnation point.

[0009] It could be helpful to provide an apparatus and a method for producing a hot-dip metal coated steel strip by which a hot-dip metal coated steel strip of high quality can be stably produced by preventing coated surface defects caused by splashing or top dross even in the case where operation conditions vary.

(Solution to Problem)

[0010] We considered that, to solve the problem stated above in a hot-dip metal coated steel strip production apparatus and method that adjust the coating weight using gas wiping nozzles, the gas temperature T at the stagnation point needs to be predicted accurately and managed within a predetermined suitable temperature range. We then conceived placing a baffle plate near a transverse edge of the steel strip and in a plane extended from the steel strip, and placing a temperature sensor on the baffle plate. Since the temperature T' measured by the temperature sensor on the baffle plate is substantially equal to the gas temperature T at the stagnation point, the gas temperature T at the stagnation point can be accurately predicted in situ. Based on the measured temperature T', the temperature of the sprayed gas (i.e. the gas temperature measured immediately after leaving a gas heater) is feedback-controlled to manage the gas temperature T at the stagnation point (to be exact, the temperature T' measured by the temperature sensor) within a predetermined suitable temperature range.

[0011] The disclosure is based on these discoveries. We thus provide:

(1) An apparatus for producing a hot-dip metal coated steel strip, comprising: a pair of gas wiping nozzles that face each other with a steel strip therebetween, and spray gas onto the steel strip from outlets thereof to adjust a coating weight on both surfaces of the steel strip, the steel strip being continuously pulled up from a molten metal bath; a supply mechanism that supplies the gas to the pair of gas wiping nozzles; a gas temperature adjusting mechanism that is capable of changing a temperature of the gas supplied from the supply mechanism to the pair of gas wiping nozzles; a baffle plate that is located near a transverse edge of the steel strip and is located in a plane extended from the steel strip, and prevents the gas sprayed from the pair of gas wiping nozzles from colliding with each other; a temperature sensor that is located on at least one surface of the baffle plate; and a controller that controls the gas temperature adjusting mechanism based on an output of the temperature sensor.

(2) The apparatus for producing a hot-dip metal coated steel strip according to (1), wherein in the case where a temperature measured by the temperature sensor is outside a predetermined range, the controller controls the gas temperature adjusting mechanism to change the temperature of the gas supplied to the pair of gas wiping nozzles so that the temperature measured by the temperature sensor is brought within the predetermined range.

(3) The apparatus for producing a hot-dip metal coated steel strip according to (1) or (2), wherein a shortest distance between the baffle plate and the transverse edge of the steel strip is 1 mm or more and less than 10 mm.

(4) The apparatus for producing a hot-dip metal coated steel strip according to any one of (1) to (3), comprising a mechanism that is capable of changing a height of the baffle plate from a bath surface of the molten metal bath.

(5) The apparatus for producing a hot-dip metal coated steel strip according to any one of (1) to (4), wherein the baffle plate is made of a material having a thermal conductivity of 1 $W \cdot m^{-1} \cdot K^{-1}$ or less.

(6) The apparatus for producing a hot-dip metal coated steel strip according to any one of (1) to (5), comprising a heat insulator located between the baffle plate and the temperature sensor.

(7) A method for producing a hot-dip metal coated steel strip using the apparatus for producing a hot-dip metal coated steel strip according to any one of (1) to (6), the method comprising spraying, while controlling the temperature of the gas supplied to the pair of gas wiping nozzles based on the output of the temperature sensor, the gas from the pair of gas wiping nozzles onto the steel strip continuously pulled up from the molten metal bath, to adjust the coating weight on the both surfaces of the steel strip.

(Advantageous Effect)

[0012] It is possible to provide an apparatus and a method for producing a hot-dip metal coated steel strip by which a hot-dip metal coated steel strip of high quality can be stably produced by preventing coated surface defects caused by splashing or top dross even in the case where operation conditions vary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the accompanying drawings:

FIG. 1 is a schematic view illustrating the structure of an apparatus 100 for producing a hot-dip metal coated steel strip according to one of the disclosed embodiments;

FIG. 2 is a perspective view illustrating the structure of the production apparatus 100 illustrated in FIG. 1 near a transverse edge of a steel strip P;

FIG. 3 is an enlarged view of a tip portion of a gas wiping nozzle 20A and a baffle plate 26 in the production apparatus 100 illustrated in FIG. 1;

FIG. 4 is a schematic view illustrating the structure of a conventional apparatus for producing a hot-dip metal coated steel strip;

FIG. 5 is a graph illustrating the splashing ratio and its standard deviation in each of Comparative Example and Examples; and

FIG. 6 is a graph illustrating the top dross quantity and its standard deviation in each of Comparative Example and Examples.

DETAILED DESCRIPTION

[0014] An apparatus 100 (hereafter also simply referred to as "production apparatus") and a method for producing a hot-dip metal coated steel strip according to one of the disclosed embodiments are described below, with reference to FIGS. 1 to 3.

[0015] As illustrated in FIG. 1, the production apparatus 100 in this embodiment includes a snout 10, a coating tank 12, a sink roll 16, and support rolls 18. The snout 10 is a member that defines the space through which a steel strip P passes, and has a rectangular section perpendicular to the steel strip traveling direction. The snout 10 has a tip immersed in a molten metal bath 14 formed in the coating tank 12. In this embodiment, the steel strip P annealed in a continuous annealing furnace with a reducing atmosphere passes through the snout 10, and is continuously introduced into the molten metal bath 14 in the coating tank 12. The steel strip P is then pulled upward from the molten metal bath 14 through the sink roll 16 and the support rolls 18 in the molten metal bath 14, and adjusted to have a predetermined coating thickness by a pair of gas wiping nozzles 20A and 20B. After this, the steel strip P is cooled, and guided to subsequent steps.

[0016] The pair of gas wiping nozzles 20A and 20B (hereafter also simply referred to as "nozzles") face each other with the steel strip P therebetween, above the coating tank 12. As illustrated in FIG. 3, the nozzle 20A sprays gas onto the steel strip P from its outlet (jet orifice 34), to adjust the coating weight on the steel strip surface. The other nozzle 20B operates in the same way. By the pair of nozzles 20A and 20B, excess molten metal is wiped away to adjust the coating weight on both surfaces of the steel strip P and also uniformize the coating weight in the sheet transverse direction and the sheet longitudinal direction.

[0017] As illustrated in FIG. 2, the nozzles 20A and 20B are each typically made longer than the steel strip width to accommodate various steel strip widths and also cope with, for example, a displacement of the steel strip in the transverse direction when pulling the steel strip up. The nozzles 20A and 20B thus each extend outward beyond the transverse edges of the steel strip. As illustrated in FIG. 3, the nozzle 20A includes an upper nozzle member 32A and a lower nozzle member 32B. The space between the respective tips of the upper and lower nozzle members 32A and 32B forms the gas jet orifice 34 (nozzle slit). The jet orifice 34 extends in the transverse direction of the steel strip. The nozzle 20A has a longitudinal section that tapers down toward the tip. The thickness of the tip portion of each of the upper and lower nozzle members 32A and 32B may be about 1 mm to 3 mm. The opening width (slit space) of the jet orifice is not limited, and may be about 0.5 mm to 2.5 mm. Gas supplied from the below-mentioned gas supply mechanism 22 passes through the gas passage defined by the upper and lower nozzle members 32A and 32B, and is ejected from the jet orifice 34 and sprayed onto the surface of the steel strip P. The other nozzle 20B has the same structure.

[0018] The following describes the gas supply mechanism 22 and a gas temperature adjusting mechanism 24. The gas supply mechanism 22 supplies gas to the nozzles 20A and 20B. The gas temperature adjusting mechanism 24 has a function of changing the temperature of the gas supplied from the gas supply mechanism 22 to the nozzles 20A and 20B. In this embodiment, the gas supply mechanism 22 includes a pipe through which gas at normal temperature passes, and a blower for pressurizing the gas to a predetermined pressure. The gas temperature adjusting mechanism 24 includes a heat exchanger. In this case, the gas pressurized by the blower is heated to a predetermined temperature by the heat exchanger, and supplied to the nozzles 20A and 20B.

[0019] The gas supply and the gas temperature adjustment are not limited to the example described above, as long as the gas temperature can be changed without delay. For example, a method of mixing combustion exhaust gas in the annealing furnace with air may be used. In this case, air is pressurized to a predetermined pressure by a blower, and then the air and the combustion exhaust gas are mixed to form mixed gas, which is supplied to the nozzles 20A and 20B. The gas temperature adjustment is performed by changing the mixing ratio of the combustion exhaust gas. In detail, to increase the gas temperature, the ratio of the combustion exhaust gas is increased. In this case, the gas supply mechanism 22 includes a pipe through which air at normal temperature passes and a blower for pressurizing the air to a predetermined pressure, and the gas temperature adjusting mechanism 24 includes a mechanism for changing the mixing ratio of the combustion exhaust gas and the air.

[0020] In this embodiment, a baffle plate 26 is located near the transverse edge of the steel strip P and in a plane extended from the steel strip P, as illustrated in FIG. 2. The baffle plate 26 is located between the pair of nozzles 20A and 20B, and prevents the gas sprayed from the pair of nozzles 20A and 20B from colliding with each other, thus contributing to reduced splashing. While FIG. 2 illustrates the baffle plate 26 located near one transverse edge of the steel strip P, the baffle plate is located near each of both transverse edges of the steel strip in this embodiment. This arrangement is preferable in terms of preventing a gas collision.

[0021] The shape of the baffle plate 26 is not limited, but is preferably rectangular as illustrated in FIG. 2. Two sides of the rectangular shape of the baffle plate 26 are preferably in parallel with the extending direction of the transverse edge of the steel strip P. The plate thickness of the baffle plate 26 is determined as appropriate in terms of ensuring stiffness, for example, preventing the baffle plate from vibrating when collided with gas. For example, the plate thickness of the baffle plate 26 may be in the range of 4 mm to 10 mm.

[0022] Locating the baffle plate 26 nearer the steel strip P contributes to higher splashing prevention performance. Thus, the shortest distance D1 between the baffle plate 26 and the transverse edge of the steel strip P greatly influences the splashing prevention performance, and is preferably 1 mm or more and less than 10 mm. If D1 is 10mm or more, splashing begins to appear rapidly. If D1 is less than 1 mm, there is a possibility that the baffle plate comes into contact with the steel strip. The baffle plate 26 extends outward beyond the edges of the nozzles 20A and 20B in the transverse direction of the steel strip.

[0023] In this embodiment, temperature sensors 28A and 28B are provided on both surfaces of the baffle plate 26, as illustrated in FIGS. 1 and 2. Temperature sensors are also provided on both surfaces of the other baffle plate (not illustrated). The form of the temperature sensors is not limited, and contact-type thermometers such as thermocouples may be used as an example. Each temperature sensor can continuously measure the temperature T' of gas sprayed onto the temperature sensor. Since the measured temperature T' is substantially equal to the gas temperature T at the stagnation point, the gas temperature T at the stagnation point can be accurately predicted in situ. Each temperature sensor outputs information of the continuously measured gas temperature T' to a controller 30.

[0024] The controller 30, having received the information of the gas temperature T' output from each temperature sensor, controls the gas temperature adjusting mechanism 24. In detail, the controller 30 feedback-controls the temperature of the sprayed gas based on the measured temperature T', to manage the gas temperature T at the stagnation point (to be exact, the temperature T' measured by the temperature sensor) within a predetermined suitable temperature range. The form of the controller 30 is not limited, and the controller 30 may be, for example, implemented by a central processing unit (CPU) in a computer.

[0025] In detail, the controller 30 controls the gas temperature adjusting mechanism 24 based on the information of the measured temperature T' received from each temperature sensor to feedback-control the temperature of the sprayed gas, in the following manner.

[0026] In the control, the average (for example, arithmetic mean) of the four measured temperatures received from the four temperature sensors is used as the measured temperature T'.

[0027] In this embodiment, it is important to manage the gas temperature T at the stagnation point (i.e. the measured temperature T') within a suitable temperature range, in terms of preventing splashing and top dross. The suitable temperature range is (the melting point of the molten metal bath) ± 100 °C. In the case of producing a hot-dip galvanized steel strip, the gas temperature T at the stagnation point (i.e. the measured temperature T') is managed within the range of zinc's melting point 420 °C ± 100 °C, that is, within the range of 320 °C to 520 °C.

[0028] A first example of the control is as follows. To constantly keep the measured temperature T' closer to a predetermined temperature (e.g. a median) in the suitable temperature range, the gas temperature is increased in the case where the measured temperature T' is less than the median, unchanged in the case where the measured temperature T' is equal to the median, and decreased in the case where the measured temperature T' is more than the median.

[0029] A second example of the control is as follows. The gas temperature is unchanged while the measured temperature T' is within the suitable temperature range, and changed only in the case where the measured temperature T' is outside the predetermined temperature range. In detail, the gas temperature is increased in the case where the measured temperature T' is less than the lower limit of the suitable temperature range, and decreased in the case where the measured temperature T' is more than the upper limit of the suitable temperature range. The temperature measured by each temperature sensor is thus kept within the suitable temperature range.

[0030] The interval at which the feedback control is performed is not limited. For example, the feedback control may be constantly performed, with the gas temperature being constantly measured continuously by each temperature sensor and the information of the measured temperature being constantly provided to the controller during operation. Alternatively, the feedback control may be intermittently performed, with the gas temperature being intermittently measured and the information of the measured temperature being provided to the controller. The constant feedback control is preferable in terms of more accurately managing the gas temperature T at the stagnation point.

[0031] As described in detail above, while controlling the temperature of the gas supplied to the gas wiping nozzles (i.e. the gas temperature measured immediately after leaving a gas heater) based on the output of each temperature sensor, the gas is sprayed from the pair of nozzles 20A and 20B onto the steel strip P continuously pulled up from the molten metal bath 14, to adjust the coating weight on both surfaces of the steel strip P. Thus, the gas temperature T at the stagnation point can be predicated accurately, and constantly maintained and managed within the predetermined suitable temperature range. This prevents coated surface defects caused by splashing or top dross, so that a hot-dip metal coated steel strip of high quality can be produced stably. These effects are achieved even in the case where the operation conditions vary.

[0032] Although this embodiment describes an example where one temperature sensor is provided on each of the both surfaces of the two baffle plates and thus total four sensors are used, the number of temperature sensors may be one, two, or three of the four. Moreover, in the case where the number of baffle plates is one, one temperature sensor may be provided on one surface (one side) of the baffle plate, or two temperature sensors made up of one temperature sensor on each of both surfaces (both sides) of the baffle plate may be provided. In the case of using a plurality of temperature sensors, the average (e.g. arithmetic mean) of the measured temperatures of the temperature sensors is set as the measured temperature T'.

[0033] The production apparatus 100 in this embodiment preferably includes a mechanism capable of changing the height of the baffle plate 26 from the bath surface of the molten metal bath so that the baffle plate 26 moves in the vertical position in accordance with the height of the nozzles 20A and 20B. In this way, even when the nozzle height is changed, the gas temperature can be always measured with the maximum collision pressure of the gas to the steel strip P, with it being possible to control the temperature of the sprayed gas with high accuracy. In detail, the baffle plate 26 is fixed to a stand (not illustrated) of the wiping nozzles. As the mechanism, pneumatic pressure may be used as an example.

[0034] An edge sensor for measuring the distance D1 to the steel strip may be preferably attached to an upper portion of the baffle plate. By moving the baffle plate in the transverse direction of the steel strip while measuring the distance to the steel strip by the edge sensor, the baffle plate 26 is positioned at a target distance D1.

[0035] In this embodiment, a heat insulator (not illustrated) is desirably provided between the baffle plate 26 and each of the temperature sensors 28A and 28B. The heat insulator is used to prevent heat transfer from the baffle plate to the temperature sensors to thus avoid a failure to accurately measure the gas temperature. The type of the heat insulator is not limited, and may be, for example, glass wool or cellulose fibers.

[0036] The same effect can be achieved by, instead of or in addition to providing the heat insulator, making the material of the baffle plate 26 a low thermal conducting material. In view of this, the baffle plate is preferably made of a material having a thermal conductivity of 1 $W \cdot m^{-1} \cdot K^{-1}$ or less. Non-limiting examples of the low thermal conducting material include ceramic such as alumina or silicon carbide.

[0037] In FIG. 3, the distance D2 between the nozzle tip and the steel strip surface is preferably in the range of 3 mm to 40 mm. If D2 is 3 mm or more, nozzle clogging caused by splashing is unlikely to occur. If D2 is 40 mm or less, the gas pressure for achieving a target coating weight can be reduced, and as a result the gas heating can be reduced.

[0038] In FIG. 3, the distance H between the center of the jet orifice 34 of the nozzle and the center of the temperature sensor 28 in the vertical direction is preferably in the range of 0 mm to 5 mm. If H is 5 mm or less, the temperature T' of the gas sprayed onto the temperature sensor can be measured more accurately.

[0039] A hot-dip metal coated steel strip produced by the disclosed production apparatus and method is, for example, a hot-dip galvanized steel sheet. Examples of the hot-dip galvanized steel sheet include a galvanized steel sheet (GI) obtained without alloying treatment after hot-dip galvanizing treatment and a galvannealed steel sheet (GA) obtained by performing alloying treatment after hot-dip galvanizing treatment.

EXAMPLES

[0040] A hot-dip galvanized steel strip production test was conducted in a hot-dip galvanized steel strip production line. The production apparatus illustrated in FIGS. 1 to 3 was used in Examples 1 to 5, and the production apparatus illustrated in FIG. 4 was used in Comparative Example. Gas wiping nozzles with a slit space of 1.2 mm were used. The gas spray direction was perpendicular to the steel strip surface. The experiment was conducted under a total of 10 sets of operation conditions, by varying the nozzle height from the hot-dip zinc molten bath surface in the range of 250 mm to 400 mm, varying the distance D2 between the nozzle tip and the steel strip surface in the range of 0 mm to 25 mm, varying the passing speed of a steel strip of 0.8 mm in sheet thickness and 1000 mm in sheet width in the range of 120 m/min to 180 m/min in line speed, and varying the gas pressure in the range of 50 kPa to 100 kPa. In all sets of operation conditions, the line speed, the gas pressure, and the distance D2 were set so as to obtain a uniform coating weight of about 50 g/m^2.

[0041] For the gas supply to the nozzles and the gas temperature adjustment, a method of supplying gas obtained by heating gas of normal temperature to a predetermined temperature by a heat exchanger and pressurizing it to a predetermined pressure by a blower was used.

[0042] In Comparative Example, no baffle plate was provided, a temperature sensor was placed at the nozzle outlet, and the experiment was conducted by performing such control of maintaining the nozzle outlet temperature Ty within the range of 320 °C to 520 °C.

[0043] In Examples 1 to 5, two baffle plates made up of one baffle plate near each of both transverse edges of the steel strip were arranged. Moreover, four temperature sensors (sheath K thermocouples) made up of one temperature sensor at a center portion of each of both surfaces of each of the baffle plates were arranged. The size of each baffle plate was 50 mm in height (dimension in the steel strip traveling direction), 200 mm in width (dimension in the steel strip transverse direction), and 5 mm in thickness. The distance D1 between each baffle plate and the transverse edge of the steel strip was 10 mm in Example 1, and 5 mm in Examples 2 to 5. The gas temperature T at the stagnation point was predicted based on the temperature measured by each temperature sensor, and the temperature of the sprayed gas was feedback-controlled. In detail, the arithmetic mean of the four measured temperatures sent from the four temperature sensors was used as the measured temperature T'. The gas temperature was unchanged in the case where the measured temperature T' was within the range of 320 °C to 520 °C, increased in the case where the measured temperature T' was less than 320 °C, and decreased in the case where the measured temperature T' was more than 520 °C. This control was continuously performed during operation.

[0044] In Examples 1 and 2, the baffle plates were made of SUS304 (thermal conductivity of 17 $W \cdot m^{-1} \cdot K^{-1}$). In Example 3, glass wool was placed between the baffle plates made of SUS304 and the temperature sensors, as a heat insulator. In Example 4, the baffle plates were made of alumina having low thermal conductivity (thermal conductivity of 0.20 $W \cdot m^{-1} \cdot K^{-1}$), and glass wool was placed between the baffle plates and the temperature sensors as a heat insulator. In Example 5, the baffle plates were made of alumina having low thermal conductivity, glass wool was placed between the baffle plates and the temperature sensors as a heat insulator, and a mechanism capable of changing the height of the baffle plates from the bath surface was used.

[0045] In each of Examples and Comparative Example, the splashing ratio and the top dross quantity were evaluated. The splashing ratio is defined as the ratio of a steel strip length judged as having a splashing defect in an inspection process to the length of the steel strip passed under each set of production conditions. Note that the splashing defect means a coated surface defect caused by (due to) splashing, the coated surface defect including a slight one which is practically insignificant. The top dross quantity is defined as the top dross weight measured by scooping up, with a ladle, top dross floating on the bath surface after sheet passing for one hour. In the experiment, the hot-dip zinc molten bath temperature was set to 460 °C.

[0046] FIG. 5 illustrates the splashing ratio under the sets of conditions. In FIG. 5, the average of splashing ratios under the 10 sets of operation conditions in each Example is normalized, with the average of splashing ratios under the 10 sets of operation conditions in Comparative Example being set to 100. The standard deviation of the splashing ratio in each of Comparative Example and Examples is illustrated, too. FIG. 6 illustrates the top dross quantity and its standard deviation under the sets of conditions.

[0047] In Example 1, the splashing ratio was reduced as compared with Comparative Example. The standard deviation σ was also reduced from 0.26 to 0.088. Thus, the splashing ratio was stably reduced under various operation conditions. The top dross quantity was equally reduced in Example 1 as compared with Comparative Example.

[0048] In Example 2, the splashing ratio and its standard deviation and the top dross quantity were further reduced as compared with Example 1. A shorter distance D1 than in Example 1 seems to contribute to higher splashing prevention effect.

[0049] In Examples 3 and 4, the splashing quantity and its standard deviation and the top dross quantity were further reduced as compared with Example 1. This can be attributed to highly accurate measurement of the temperature T' of the gas sprayed onto the temperature sensors.

[0050] In Example 5, the splashing quantity and its standard deviation and the top dross quantity were further reduced as compared with Examples 3 and 4. This can be attributed to highly accurate measurement of the temperature T' of the gas sprayed onto the temperature sensors by moving the baffle plates in the vertical direction, in addition to the effect of the heat insulator.

INDUSTRIAL APPLICABILITY

[0051] The disclosed apparatus and method for producing a hot-dip metal coated steel strip can stably produce a hot-dip metal coated steel strip of high quality by preventing coated surface defects caused by splashing or top dross even in the case where operation conditions vary.

REFERENCE SIGNS LIST

[0052]

100	apparatus for producing hot-dip metal coated steel strip
10	snout
12	coating tank
14	molten metal bath
16	sink roll
18	support roll
.20A, 20B	gas wiping nozzle
22	gas supply mechanism
24	gas temperature adjusting mechanism
26	baffle plate
28A, 28B	temperature sensor
30	controller
32A	upper nozzle member
32B	lower nozzle member
34	jet orifice (outlet)
P	steel strip

Claims

1. An apparatus for producing a hot-dip metal coated steel strip, comprising:

a pair of gas wiping nozzles that face each other with a steel strip therebetween, and spray gas

onto the steel strip from outlets thereof to adjust a coating weight on both surfaces of the steel strip, the steel strip being continuously pulled up from a molten metal bath;
a supply mechanism that supplies the gas to the pair of gas wiping nozzles;
a gas temperature adjusting mechanism that is capable of changing a temperature of the gas supplied from the supply mechanism to the pair of gas wiping nozzles;
a baffle plate that is located near a transverse edge of the steel strip and is located in a plane extended from the steel strip, and prevents the gas sprayed from the pair of gas wiping nozzles from colliding with each other;
a temperature sensor that is located on at least one surface of the baffle plate; and
a controller that controls the gas temperature adjusting mechanism based on an output of the temperature sensor.

2. The apparatus for producing a hot-dip metal coated steel strip according to claim 1,
wherein in the case where a temperature measured by the temperature sensor is outside a predetermined range, the controller controls the gas temperature adjusting mechanism to change the temperature of the gas supplied to the pair of gas wiping nozzles so that the temperature measured by the temperature sensor is brought within the predetermined range.

3. The apparatus for producing a hot-dip metal coated steel strip according to claim 1 or 2,
wherein a shortest distance between the baffle plate and the transverse edge of the steel strip is 1 mm or more and less than 10 mm.

4. The apparatus for producing a hot-dip metal coated steel strip according to any one of claims 1 to 3, comprising
a mechanism that is capable of changing a height of the baffle plate from a bath surface of the molten metal bath.

5. The apparatus for producing a hot-dip metal coated steel strip according to any one of claims 1 to 4,
wherein the baffle plate is made of a material having a thermal conductivity of 1 $W \cdot m^{-1} \cdot K^{-1}$ or less.

6. The apparatus for producing a hot-dip metal coated steel strip according to any one of claims 1 to 5, comprising
a heat insulator located between the baffle plate and the temperature sensor.

7. A method for producing a hot-dip metal coated steel strip using the apparatus for producing a hot-dip metal coated steel strip according to any one of claims 1 to 6, the method comprising
spraying, while controlling the temperature of the gas supplied to the pair of gas wiping nozzles based on the output of the temperature sensor, the gas from the pair of gas wiping nozzles onto the steel strip continuously pulled up from the molten metal bath, to adjust the coating weight on the both surfaces of the steel strip.

FIG. 1

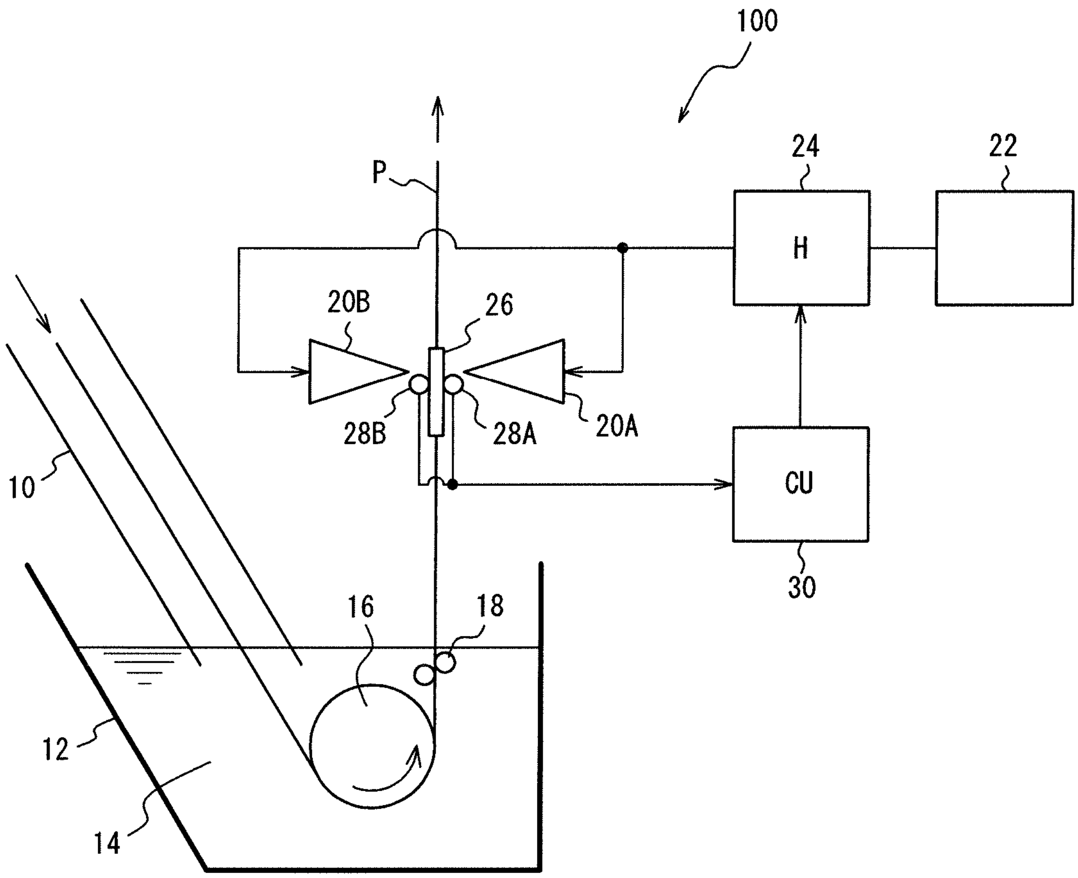


FIG. 2

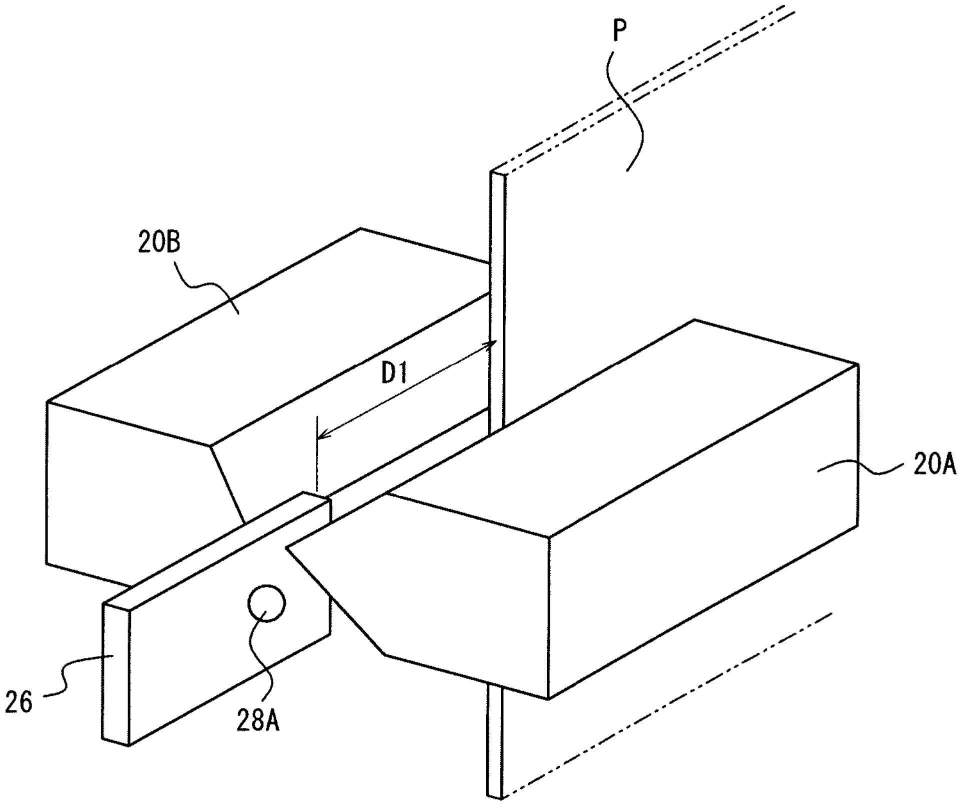


FIG. 3

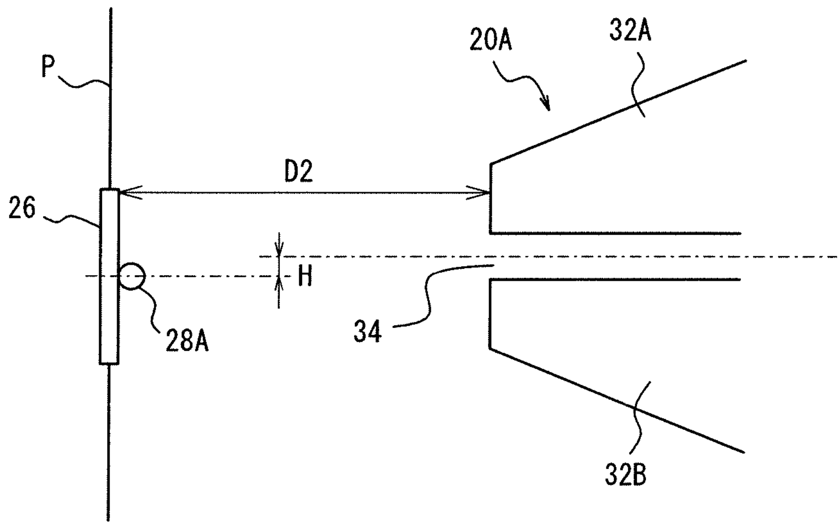


FIG. 4

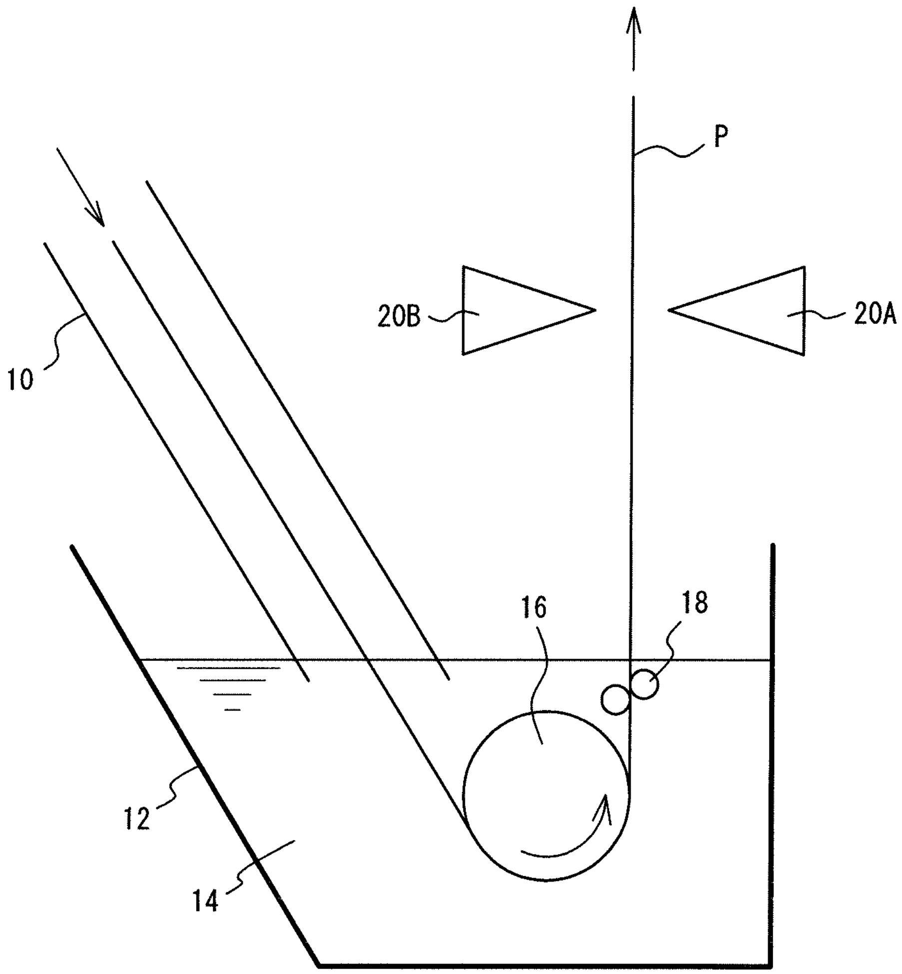
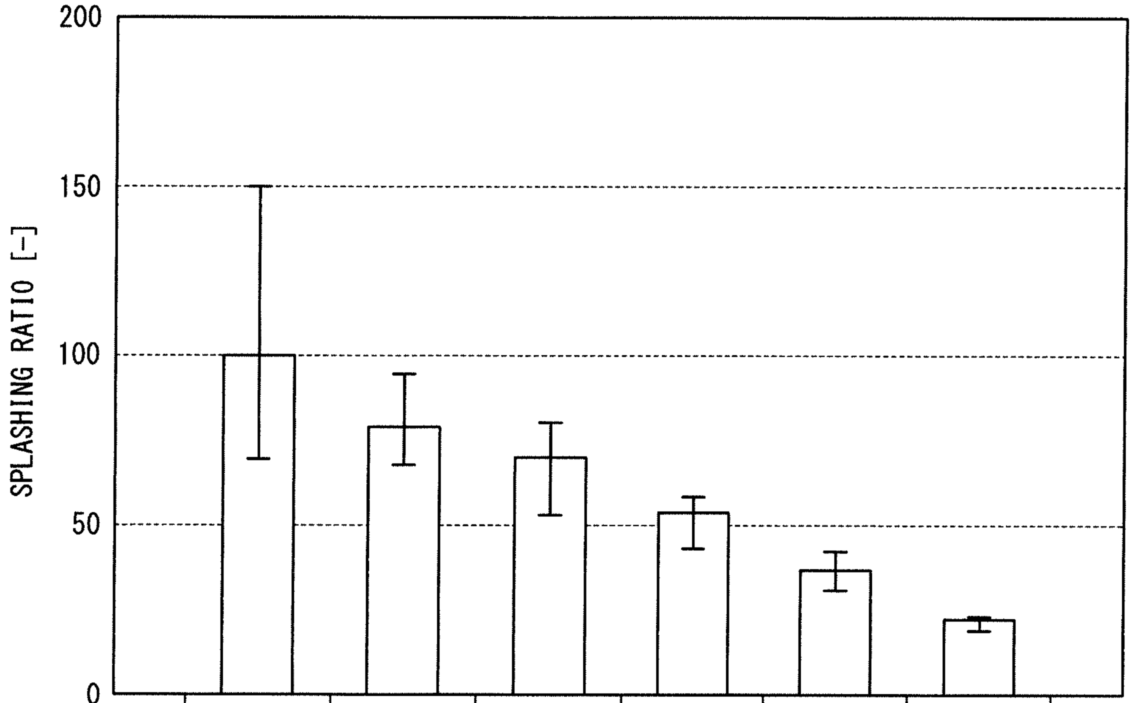
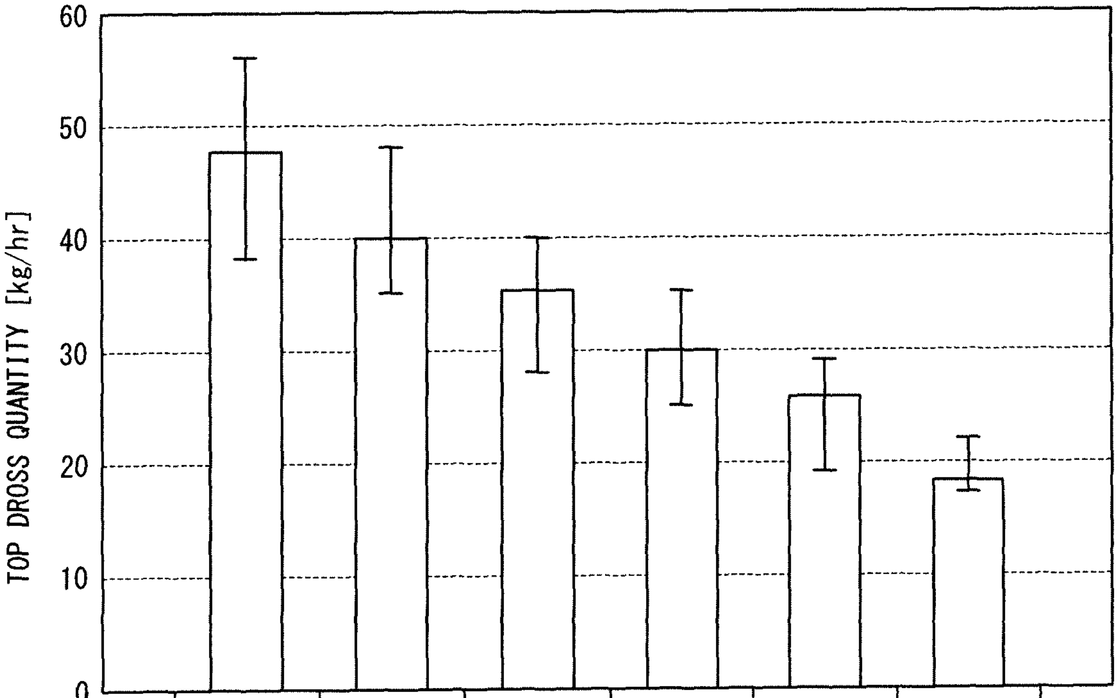


FIG. 5



	COMPARATIVE EXAMPLE	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	EXAMPLE 4	EXAMPLE 5
σ	0. 260	0. 088	0. 071	0. 052	0. 033	0. 023

FIG. 6



	COMPARATIVE EXAMPLE	EXAMPLE 1	EXAMPLE 2	EXAMPLE 3	EXAMPLE 4	EXAMPLE 5
σ	5.58	4.53	3.77	3.36	2.80	1.75

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/002007

A. CLASSIFICATION OF SUBJECT MATTER
C23C2/20(2006.01)i, *C23C2/00*(2006.01)i, *C23C2/40*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C23C2/20, C23C2/00, C23C2/40

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 6-172955 A (Sumitomo Metal Industries, Ltd.), 21 June 1994 (21.06.1994), claims; fig. 1 (Family: none)	1-7
A	JP 2005-256050 A (Nisshin Steel Co., Ltd.), 22 September 2005 (22.09.2005), claims; fig. 1 (Family: none)	1-7

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 2016 (30.06.16)	12 July 2016 (12.07.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2009203500 A **[0006] [0007]**
- JP 2009263698 A **[0006] [0007]**