production of a hot-dip Zn alloy-plated steel sheet is restricted in some cases. For example, the feed rate of a plated steel sheet having a large thickness is required to be slow so that the plated steel sheet is cooled to a specified temperature, resulting in reduced productivity. In addition, in the case of adding readily oxidizable elements into a plating bath, the readily oxidizable elements tend to form a dross. Consequently, complicated concentration control of the readily oxidizable elements is required, resulting in a complicated production process, which has been a problem.

[0008] Embodiments of the present invention is to provide a hot-dip Zn alloy-plated steel sheet excellent in blackening resistance which can be produced without reduction in productivity and without complicated control of the components of a plating bath.

Solution to Problem

[0009] The present inventors have found that the problem can be solved by forming a composite oxide film containing the constituent components of a plating layer and vanadium on the surface of the plating layer and reducing the ratio of Zn hydroxide contained in the composite oxide film, and accomplished the present invention through further study.

[0010] Embodiments of the present invention relate to the following hot-dip Zn alloy-plated steel sheet.

[0011]

According to an aspect, there is provided a method of producing a hot-dip Zn alloy-plated steel sheet comprising: dipping a base steel sheet in a hot-dip Zn alloy plating bath to form a hot-dip Zn alloy plating layer on a surface of the base steel sheet; and contacting an aqueous solution containing a vanadium compound with a surface of the hot-dip Zn alloy plating layer to cool the base steel sheet and the hot-dip Zn alloy plating layer having a raised temperature through formation of the hot-dip Zn alloy plating layer and to form a composite oxide film on a surface of the hot-dip Zn alloy plating layer; wherein a temperature of the surface of the hot-dip Zn alloy plating layer when the aqueous solution is to be contacted with the surface of the hot-dip Zn alloy plating layer is equal to or more than 100°C and equal to or less than a solidifying point of the hot-dip Zn alloy plating layer; and the composite oxide film comprises constituent components of the hot-dip Zn alloy plating layer and vanadium, and the composite oxide film satisfies, at a whole of a surface of the composite oxide film, following Equation 1:

$$\frac{S[Hydroxide]}{S[Hydroxide]+S[Oxide]}\times 100 \leq 40 \quad \text{(Equation 1)}$$

S[Oxide] is a peak area derived from Zn oxide and centered at approximately 1022 eV in an intensity profile of the XPS analysis of the surface of the composite oxide film; and S[Hydroxide] is a peak area derived from Zn hydroxide and centered at approximately 1023 eV in the intensity profile of the XPS analysis of the surface of the composite oxide

film.

In an embodiment, the hot-dip Zn alloy plating layer comprises 1.0 to 22.0% by mass of Al, 0.1 to 10.0% by mass of Mg, and the balance of the hot-dip Zn alloy plating layer being Zn and unavoidable impurities.

In an embodiment, the hot-dip Zn alloy plating layer further comprises at least one selected from the group consisting of 0.001 to 2.0% by mass of Si, 0.001 to 0.1% by mass of Ti, and 0.001 to 0.045% by mass of B.

In an embodiment, the adhering amount of the vanadium contained in the composite oxide film is in the range of 0.01 to 10.0 mg/m^2.

Advantageous Effects of Invention

[0012] According to embodiments of the present invention, a hot-dip Zn alloy-plated steel sheet excellent in blackening resistance can be easily produced at high productivity.

Brief Description of Drawings

[0013]

FIGS. 1A to 1D illustrate the intensity profiles of the chemical binding energy

cooled in water quenching zone 360. Water quenching zone 360 is a facility for cooling the steel strip S through contact with a large amount of cooling water in comparison with mist cooling zone 350, supplying an amount of water to form a temporary water film on the surface of the plating layer. For example, water quenching zone 360 includes headers having 10 flat spray nozzles disposed at intervals of 150 mm in the width direction of the steel strip S, which are disposed in 7 rows in the feeding direction of the base steel sheet S. In water quenching zone 360, an aqueous solution containing a vanadium compound is used as cooling aqueous solution. The steel strip S is cooled in water quenching zone 360, with the cooling aqueous solution in an amount to temporarily form a water film on the surface of the plating layer being supplied. For example, the cooling aqueous solution has a water temperature of approximately 20°C, a water pressure of approximately 2.5 kgf/cm^2, and a water quantity of approximately 150 m^3/h. The phrase "a water film is temporarily formed" means a state allowing a water film in contact with a hot-dip Zn alloy-plated steel sheet to be visually observed for approximately one second or more. Through cooling using an aqueous solution of a vanadium compound in water quenching zone 360, a composite oxide film containing the constituent components of a plating layer and vanadium with a Zn hydroxide of 40% or less is formed on the surface of the plating layer.

[0046] The water-cooled hot-dip Zn alloy-plated steel sheet is rolled for thermal refining by skin pass mill 370, corrected to flat by tension leveler 380, and then wound onto tension reel 390.

[0047] When a chemical conversion coating is further formed on the surface of a plating layer, a specified chemical conversion treatment liquid is applied to the surface of the hot-dip Zn alloy-plated steel sheet corrected by tension leveler 380, with roll coater 400. The hot-dip Zn alloy-plated steel sheet through the chemical conversion treatment is dried and cooled in drying zone 410 and air cooling zone 420, and then wound onto tension reel

CLAIMS:

1. A method of producing a hot-dip Zn alloy-plated steel sheet comprising:

dipping a base steel sheet in a hot-dip Zn alloy plating bath to form a hot-dip Zn alloy plating layer on a surface of the base steel sheet; and

contacting an aqueous solution containing a vanadium compound with a surface of the hot-dip Zn alloy plating layer to cool the base steel sheet and the hot-dip Zn alloy plating layer having a raised temperature through formation of the hot-dip Zn alloy plating layer and to form a composite oxide film on a surface of the hot-dip Zn alloy plating layer;

wherein a temperature of the surface of the hot-dip Zn alloy plating layer when the aqueous solution is to be contacted with the surface of the hot-dip Zn alloy plating layer is equal to or more than 100°C and equal to or less than a solidifying point of the hot-dip Zn alloy plating layer; and

the composite oxide film comprises constituent components of the hot-dip Zn alloy plating layer and vanadium, and the composite oxide film satisfies, at a whole of a surface of the composite oxide film, following Equation 1:

$$\frac{S[Hydroxide]}{S[Hydroxide]+S[Oxide]}\times 100 \leq 40 \quad \text{(Equation 1)}$$

S[Oxide] is a peak area derived from Zn oxide and centered at approximately 1022 eV in an intensity profile of the XPS analysis of the surface of the composite oxide film; and S[Hydroxide] is a peak area derived from Zn hydroxide and centered at approximately 1023 eV in the intensity profile of the XPS analysis of the surface of the composite oxide film.

2. The method of producing a hot-dip Zn alloy-plated steel sheet according to claim 1, wherein:

the hot-dip Zn alloy plating layer comprises 1.0 to 22.0% by mass of A1, 0.1 to 10.0% by mass of Mg, and the balance of the hot-dip Zn alloy plating layer being Zn and unavoidable impurities.

3. The method of producing a hot-dip Zn alloy-plated steel sheet according to claim 2, wherein:

the hot-dip Zn alloy plating layer further comprises at least one selected from the group consisting of 0.001 to 2.0% by mass of Si, 0.001 to 0.1% by mass of Ti, and 0.001 to 0.045% by mass of B.

4. The method of producing a hot-dip Zn alloy-plated steel sheet according to any one of claims 1 to 3, wherein an adhering amount of the vanadium contained in the composite oxide film is in the range of 0.01 to 10.0 mg/m^2.