

SPECIFICATION

Title of the Invention: HOT-DIP PLATED STEEL SHEET

Technical Field of the Invention

[0001]

5 The present invention relates to a hot-dip plated steel sheet. The present application claims priority based on Japanese Patent Application No. 2022-094349 filed in Japan on June 10, 2022, the contents of which are incorporated herein by reference.

Related Art

[0002]

10 Zn-Al-Mg-based hot-dip plated steel sheets, having higher corrosion resistance than hot-dip galvanized steel sheets, are widely used in various manufacturing industries such as building materials, home electric appliances, and automobile fields. The use amount thereof has increased in recent years.

[0003]

15 In order to show characters, patterns, design drawings, or the like on the surface of the hot-dip plating layer of a hot-dip plated steel sheet, the hot-dip plating layer may be subjected to processes such as printing or painting to show characters, patterns, design drawings, or the like on the surface of the hot-dip plating layer.

[0004]

20 However, there is a problem in that the cost and time increase to apply characters, designs, and the like when the hot-dip plating layer is subjected to processes such as printing or painting. Furthermore, when characters, designs, and the like are shown on the surface of the plating layer by printing or painting, not only the metallic luster appearance, which is highly favored by consumers, is lost. Due to the problem
25 that the coating film itself is degraded with time and the adhesion of the coating film is

degraded with time, the durability is poor, and the characters, designs, and the like may disappear over time.

[0005]

Therefore, as disclosed in Patent Document 1, a technique has been proposed in
5 which characters, designs, and the like are shown on the surface of the plating layer of a Zn-Al-Mg-based hot-dip plated steel sheet.

Citation List

Patent Document

[0006]

10 Patent Document 1: Japanese Patent No. 6648871

Summary of Invention

Problems to be Solved by the Invention

[0007]

The Zn-Al-Mg-based hot-dip plated steel sheet disclosed in Patent Document 1
15 is capable of forming an intentional pattern made of a straight portion, a curved portion, a figure, a number, a symbol, and a character, or a combination thereof on the surface of the plating layer, without ink application or grinding processing. As a result, for example, a manufacturer's name, a manufacturing number, a mark including a combination of characters and shapes, and the like can be shown on the surface of the
20 plating layer, which is advantageous in facilitating steel sheet management or the like.

[0008]

However, although these intentional patterns are useful, there is a demand from consumers and the like that, in a component, a product, a structure, or the like made of a hot-dip plated steel sheet on which a pattern is formed, the pattern can be easily
25 distinguished by human vision when light is incident from a specific direction, and the

pattern is difficult to distinguish when light is incident from other directions.

[0009]

The present invention has been made in view of the above circumstances, and an object of the present invention is to provide a hot-dip plated steel sheet in which the pattern such as characters and designs shown on the surface of the plating layer can be easily distinguished by human vision when light is incident from a specific direction, and the pattern can be difficult to distinguish when light is incident from other directions.

Means for Solving the Problem

[0010]

In order to solve the above problem, the present invention employs the following configurations.

[1] A hot-dip plated steel sheet, including: a steel sheet; and a hot-dip plating layer formed on a surface of the steel sheet, wherein

the hot-dip plating layer includes, as an average composition, 4 to 22 mass% of

Al and 1.0 to 10 mass% of Mg, and includes a balance including Zn and impurities,

the hot-dip plating layer includes a pattern part and a non-pattern part, and

for incident light having an incident angle in a range of 0° to less than 90°

against a normal-line direction of the surface of the steel sheet, reflected light from the

pattern part in the normal-line direction and reflected light from the non-pattern part in

the normal-line direction have a relationship such that formula (1) and formula (2) below are satisfied:

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1), \text{ and}$$

$$|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2),$$

herein,

I_{PH} : reflection intensity from the pattern part in the normal-line direction for

incident light having an incident angle of 0° to less than 35°,

I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°,

I_{PM} : reflection intensity from the pattern part in the normal-line direction for
5 incident light having an incident angle of 35° to 80°,

I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 35° to 80°,

I_{PL} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°, and

10 I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°.

[2] A hot-dip plated steel sheet, including: a steel sheet; and a hot-dip plating layer formed on a surface of the steel sheet, wherein

the hot-dip plating layer includes, as an average composition, 4 to 22 mass% of
15 Al and 1.0 to 10 mass% of Mg, and includes a balance including Zn and impurities, and further includes one or two selected from a group consisting of the following group A and group B,

the hot-dip plating layer includes a pattern part and a non-pattern part, and

for incident light having an incident angle in a range of 0° to less than 90°

20 against a normal-line direction of the surface of the steel sheet, reflected light from the pattern part in the normal-line direction and reflected light from the non-pattern part in the normal-line direction have a relationship such that formula (1) and formula (2) below are satisfied:

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1), \text{ and}$$

25 $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2),$

[Group A] 0.0001 to 2 mass% of Si, and

[Group B] 0.0001 to 2 mass% in total of at least one of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf, and C,

herein,

5 I_{PH} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35° ,

I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35° ,

10 I_{PM} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 35° to 80° ,

I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 35° to 80° ,

I_{PL} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° , and

15 I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° .

[3] The hot-dip plated steel sheet according to [1] or [2], wherein the pattern part is arranged in a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a dot portion, a figure, a number, a symbol, and a character.

20 [4] The hot-dip plated steel sheet according to [1] or [2], wherein an adhesion amount of the hot-dip plating layer is 30 to 600 g/m² in total of both surfaces of the steel sheet.

[5] The hot-dip plated steel sheet according to [3], wherein an adhesion amount of the hot-dip plating layer is 30 to 600 g/m² in total of both surfaces of the steel sheet.

25 [6] The hot-dip plated steel sheet according to [2], wherein the hot-dip plating

layer has an average composition including the group A in terms of mass%.

[7] The hot-dip plated steel sheet according to [2], wherein the hot-dip plating layer has an average composition including the group B in terms of mass%.

[8] The hot-dip plated steel sheet according to [1] or [2], wherein, in the pattern part, a ratio of an inclined surface having an inclination angle of 17 to 40° is 60% or more.

Effects of the Invention

[0011]

According to the present invention, the pattern such as characters and designs shown on the surface of the plating layer can be distinguished by human vision when light is incident from a specific direction, and the pattern can be difficult to distinguish when light is incident from other directions.

Brief Description of the Drawings

[0012]

FIG. 1 is a schematic diagram illustrating the intensity of reflected light for each incident angle in the pattern part and the non-pattern part.

FIG. 2 is a schematic diagram showing the intensity of reflected light for each incident angle in the pattern part and the non-pattern part of a hot-dip plated steel sheet of an embodiment of the present invention.

Embodiments of the Invention

[0013]

The hot-dip plated steel sheet of an embodiment of the present invention will be described.

The hot-dip plated steel sheet of the embodiment includes a steel sheet; and a hot-dip plating layer formed on a surface of the steel sheet, wherein the hot-dip plating

layer includes, as an average composition, 4 to 22 mass% of Al and 1.0 to 10 mass% of Mg, and includes a balance including Zn and impurities, the hot-dip plating layer includes a pattern part and a non-pattern part formed therein in plane view, and for incident light having an incident angle in a range of 0° to less than 90° against a normal-
5 line direction of the surface of the steel sheet, reflected light from the pattern part in the normal-line direction and reflected light from the non-pattern part in the normal-line direction have a relationship such that formula (1) and formula (2) below are satisfied.

[0014]

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1)$$

10 $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2)$

[0015]

Herein, I_{PH} , I_{BH} , I_{PM} , I_{BM} , I_{PL} , and I_{BL} are as follows.

I_{PH} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°

15 I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°

I_{PM} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 35° to 80°

20 I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 35° to 80°

I_{PL} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°

I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°

25 [0016]

The material of the steel sheet as the base of the hot-dip plating layer is not particularly limited. Although details will be described later, general steel or the like can be used as the material without particular limitation, Al killed steel or some high alloy steel can also be applied, and the shape is also not particularly limited. The hot-dip plating layer of the embodiment is formed by applying the hot-dip plating method described later to the steel sheet.

[0017]

Next, the chemical composition of the hot-dip plating layer will be described.

The hot-dip plating layer includes, as an average composition, 4 to 22 mass% of Al and 1.0 to 10 mass% of Mg, and includes Zn and impurities as a balance. More preferably, the hot-dip plating layer includes, as an average composition, 4 to 22 mass% of Al and 1.0 to 10 mass% of Mg, and includes a balance consisting of Zn and impurities. The hot-dip plating layer may include 0.0001 to 2 mass% of Si as an average composition.

[0018]

Further, the hot-dip plating layer may include one or two selected from a group consisting of the following group A and group B.

[Group A] 0.0001 to 2 mass% of Si

[Group B] 0.0001 to 2 mass% in total of at least one of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf, and C

[0019]

The Al content is in a range of 4 to 22 mass% as an average composition. Al is preferably included in order to ensure corrosion resistance. When the Al content is 4 mass% or more in the hot-dip plating layer, the effect of improving corrosion resistance is further enhanced. When the content is more than 22 mass%, the effect of improving

corrosion resistance is not only saturated, but also may be deteriorated. From the viewpoint of corrosion resistance, the lower limit of the Al content is preferably 6 mass%, and more preferably 11 mass%. The upper limit of the Al content is preferably 19 mass%.

5 [0020]

The Mg content is in a range of 1.0 to 10 mass% as an average composition. Mg is preferably included in order to improve corrosion resistance. When the Mg content is 1.0 mass% or more in the hot-dip plating layer, the effect of improving corrosion resistance is further enhanced. However, when Mg exceeds 10 mass%, dross
10 occurs significantly in the plating bath so that the hot-dip plated steel sheet is difficult to stably manufacture. Therefore, the Mg content is 10 mass% or less. From the viewpoint of the balance between corrosion resistance and dross generation, the lower limit of the Mg content is preferably 1.5 mass%, and more preferably 2.0 mass%. The upper limit of the Mg content is preferably 8.0 mass%, and more preferably 6.0 mass%
15 as a range.

[0021]

The hot-dip plating layer may include 0.0001 to 2.0 mass% of Si as an average composition. Si is an element effectively improving the adhesion of the hot-dip plating layer. When Si is included in an amount of 0.0001 mass% or more in the hot-dip
20 plating layer, the effect of improving adhesion is exhibited. Therefore, Si is preferably included in an amount of 0.0001 mass% or more. On the other hand, even when Si is included in an amount of more than 2 mass%, the effect of improving adhesion of the plating is saturated. Therefore, the Si content is 2 mass% or less even when the hot-dip plating layer includes Si. From the viewpoint of adhesion of the plating, the lower limit
25 of the Si content may be 0.0010 mass%, or may be 0.0100 mass% in the hot-dip plating

layer. From the viewpoint of adhesion of the plating, the upper limit of the Si content may be 1 mass%, or may be 0.8 mass% in the hot-dip plating layer.

[0022]

The hot-dip plating layer may include, as an average composition, 0.0001 to 2 mass% in total of at least one of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf, and C. When these elements are included, the hot-dip plating layer is able to have further improved corrosion resistance. REM is at least one of rare earth elements, which have atomic numbers 57 to 71 in the periodic table.

[0023]

In the chemical composition of the hot-dip plating layer, the balance is zinc and impurities. The impurities are other than zinc, and are inevitably included in the base metal, or included when steel is melted in a plating bath.

[0024]

The average composition of the hot-dip plating layer can be measured by the following method. First, the surface layer coating film is removed with a coating film-peeling agent that does not erode the plating (for example, NEOREVER SP-751, manufactured by SANSAIKAKO); then the hot-dip plating layer is dissolved with hydrochloric acid containing an inhibitor (for example, HIBIRON, manufactured by Sugimura Chemical Industrial Co.,Ltd.); and the resulting solution is subjected to inductively coupled plasma (ICP) emission spectrometry. When there is no surface layer coating film, the work of removing the surface layer coating film can be omitted.

[0025]

Next, the microstructure of the hot-dip plating layer will be described. The microstructure of the hot-dip plating layer in the embodiment may have, for example, a microstructure as described below. As a result, the hot-dip plating layer has a satin

surface appearance, and has excellent aesthetic appearance. The microstructure of the hot-dip plating layer can be obtained as long as the plating has the above chemical composition. Therefore, in the present invention, there is no need to limit the microstructure of the hot-dip plating layer.

5 [0026]

The hot-dip plating layer including Al, Mg, and Zn includes an [Al phase] and an [Al/Zn/MgZn₂ ternary eutectic structure]. Specifically, the base [Al/Zn/MgZn₂ ternary eutectic structure] includes the [Al phase]. Further, the base [Al/Zn/MgZn₂ ternary eutectic structure] may include an [MgZn₂ phase] or a [Zn phase]. When Si is included, the base [Al/Zn/MgZn₂ ternary eutectic structure] may include an [Mg₂Si phase].

[0027]

[Al/Zn/MgZn₂ ternary eutectic structure]

The [Al/Zn/MgZn₂ ternary eutectic structure] is a ternary eutectic structure of an Al phase, a Zn phase, and an intermetallic compound MgZn₂ phase. For example, the Al phase forming the ternary eutectic structure corresponds to the "Al" phase" (Al solid solution solid-dissolving Zn, and including a small amount of Mg) at high temperatures in the ternary system equilibrium state diagram of Al-Zn-Mg.

The Al" phase at high temperatures usually appears separated into a fine Al phase and a fine Zn phase at normal temperature. The Zn phase in the ternary eutectic structure is a Zn solid solution in which a small amount of Al is solid-dissolved, and in some cases, a small amount of Mg is further solid-dissolved. The MgZn₂ phase in the ternary eutectic structure is an intermetallic compound phase present in the vicinity of Zn: about 84 mass% in the binary system equilibrium state diagram of Zn-Mg.

25 As seen in the state diagram, it is considered that each phase does not solid-

dissolve other additive elements, or solid-dissolves an extremely small amount thereof. However, since the amount thereof cannot be clearly distinguished by ordinary analysis, the ternary eutectic structure composed of the three phases is referred to as the [Al/Zn/MgZn₂ ternary eutectic structure] in the present specification.

5 [0028]

[Al phase]

The [Al phase] is a phase that looks like an island with a clear boundary in the base ternary eutectic structure. For example, the phase corresponds to the "Al" phase" (Al solid solution solid-dissolving Zn, and including a small amount of Mg) at high
10 temperatures in the ternary system equilibrium state diagram of Al-Zn-Mg. In the Al" phase at high temperatures, the amount of solid-dissolved Zn and Mg differs depending on the concentration of Al and Mg in the plating bath. The Al" phase at high temperatures is usually separated into a fine Al phase and a fine Zn phase at normal temperature. However, the island-like shape observed at normal temperature is
15 presumably due to the shape of the Al" phase at high temperatures.

As seen in the state diagram, it is considered that the phase does not solid-dissolve other additive elements, or solid-dissolves an extremely small amount thereof. However, since the amount thereof cannot be clearly distinguished by ordinary analysis, the phase that is derived from the Al" phase at high temperatures and has a shape due to
20 the shape of the Al" phase is referred to as the [Al phase] in the present specification.

The [Al phase] can be clearly distinguished from the Al phase forming the ternary eutectic structure in microscopic observation.

[0029]

[Zn phase]

25 The [Zn phase] is a phase that looks like an island with a clear boundary in the

base ternary eutectic structure. Actually, the phase may solid-dissolve a small amount of Al and a small amount of Mg. As seen in the state diagram, it is considered that the phase does not solid-dissolve other additive elements, or solid-dissolves an extremely small amount thereof.

5 The [Zn phase] can be clearly distinguished from the Zn phase forming the ternary eutectic structure in microscopic observation. The hot-dip plating layer of the embodiment may include the [Zn phase] depending on manufacturing conditions. However, the corrosion resistance is hardly affected by the [Zn phase]. Therefore, even if the [Zn phase] is included in the hot-dip plating layer, there is no particular problem.

10 [0030]

[MgZn₂ phase]

The [MgZn₂ phase] is a phase that looks like an island with a clear boundary in the base ternary eutectic structure. Actually, the phase may solid-dissolve a small amount of Al. As seen in the state diagram, it is considered that the phase does not
15 solid-dissolve other additive elements, or solid-dissolves an extremely small amount thereof.

The [MgZn₂ phase] can be clearly distinguished from the MgZn₂ phase forming the ternary eutectic structure in microscopic observation. The [MgZn₂ phase] is not included in the hot-dip plating layer of the embodiment in some manufacturing
20 conditions, but is included in the hot-dip plating layer in most manufacturing conditions.

[0031]

[Mg₂Si phase]

The [Mg₂Si phase] is a phase that looks like an island with a clear boundary in the solidified microstructure of the plating layer to which Si is added. As seen in the
25 state diagram, it is considered that the [Mg₂Si phase] does not solid-dissolve Zn, Al, or

other additive elements, or solid-dissolves an extremely small amount thereof. The [Mg₂Si phase] can be clearly distinguished from other phases in the hot-dip plating layer by microscopic observation.

[0032]

5 In the embodiment, the hot-dip plating layer is formed as follows: the steel sheet is immersed in a plating bath and then pulled up; and thereafter, the molten metal adhering on the sheet surface is solidified. At this time, the [Al phase] is first formed, and then the [Al/Zn/MgZn₂ ternary eutectic structure] is formed as the temperature of the molten metal decreases. Depending on the chemical composition of the hot-dip plating
10 layer (that is, the chemical composition of the plating bath), the [Mg₂Si phase], the [MgZn₂ phase], or the [Zn phase] may be formed in the base [Al/Zn/MgZn₂ ternary eutectic structure].

[0033]

Next, the pattern part and the non-pattern part in the surface of the hot-dip
15 plating layer will be described.

[0034]

In the embodiment, in the surface of the hot-dip plating layer, a pattern part and a non-pattern part are formed. The pattern part and the non-pattern part may be arranged in a predetermined shape. In plane view, the pattern part is preferably
20 arranged in a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a dot portion, a figure, a number, a symbol, and a character. It can be said that the pattern part having such a shape is intentionally formed. In the pattern part, each of the straight portion and the curved portion preferably has such a width that it can be visually recognized as described later, and has a length of 1 mm or
25 more. In the pattern part, the dot portion preferably has a circle equivalent diameter of

1 mm or more and less than 10 mm. Further preferably, a plurality of dot portions is regularly arranged. When the pattern part is a figure, a number, a symbol, or a character, it is preferable that these shapes can be visually recognized as described later. It can be said that the pattern part having such a size and shape is further intentionally
5 formed. The non-pattern part is the region other than the pattern part. In addition, the shape of the pattern part is allowed as long as it can be recognized as a whole even if a part of the pattern part is missing, such as a missing dot. The non-pattern part may have a shape that borders the boundary of the pattern part.

[0035]

10 When the surface of the hot-dip plating layer is arranged with a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a dot portion, a figure, a number, a symbol, and a character, the region can be defined as the pattern part, and the other region can be defined as the non-pattern part. The pattern part preferably has these artificially formed shapes.

15 The boundary between the pattern part and the non-pattern part can be grasped with the naked eye. The boundary between the pattern part and the non-pattern part may be visually grasped from an enlarged image obtained by an optical microscope, a magnifying glass, or the like.

[0036]

20 The pattern part is formed in such a size that the presence of the pattern part can be visually recognized with the naked eye or using a magnifying glass or a microscope. The non-pattern part is a region occupying most of the hot-dip plating layer (the surface of the hot-dip plating layer), and the pattern part may be arranged in the non-pattern part.

From the viewpoint of improving the visibility of the pattern part, the area ratio
25 of the pattern part to the surface of the hot-dip plating layer is preferably significantly

smaller than that of the non-pattern part. For example, the area ratio of the pattern part to the surface of the hot-dip plating layer is preferably 30% or less, 25% or less, 20% or less, 15% or less, 10% or less, or 5% or less.

[0037]

5 The pattern part is arranged in a predetermined shape in the non-pattern part. Specifically, the pattern part is arranged in the non-pattern part in a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a figure, a dot portion, a figure, a number, a symbol, and a character. By intentionally adjusting the shape of the pattern part, the surface of the hot-dip plating layer shows a shape that is any
10 one, or a combination of two or more, of a straight portion, a curved portion, a figure, a dot portion, a figure, a number, a symbol, and a character. For example, the surface of the hot-dip plating layer shows a character string, a numeric string, a symbol, a mark, a line drawing, a design drawing, a combination thereof, or the like, each of which is made of the pattern part. This shape is intentionally or artificially formed by the
15 manufacturing method described later, and is not formed naturally. A person skilled in the art who knows the appearance of an ordinary hot-dip plating layer can easily distinguish between the artificially shaped pattern part and the non-pattern part. In the present specification, for example, the difference in appearance between the pattern part and the non-pattern part is not because of the difference in the crystal structure of the
20 metallographic structure, the presence or absence of invisible minute defects, and the like are reflected to the appearance of the hot-dip plated steel sheet.

[0038]

When reflected light from the pattern part and reflected light from the non-pattern part are different in strength for light incident on the hot-dip plating layer from a
25 specific direction, the pattern part and the non-pattern part are easily distinguished from

each other in human vision. On the other hand, when reflected light from the pattern part and reflected light from the non-pattern part are not different or slightly different in strength, the pattern part and the non-pattern part are difficult to distinguish from each other in human vision. Therefore, in the embodiment, the surface form of the hot-dip plating layer is controlled. Thereby, reflected light from the pattern part and reflected light from the non-pattern part are significantly different in strength for incident light from a specific direction, and reflected light from the pattern part and reflected light from the non-pattern part are slightly different in strength for incident light from directions other than a specific direction. As a result, the pattern part can be distinguished only when light is incident from a specific direction. The specific direction is the range of 35 to 80° against the normal-line direction of the surface of the steel sheet.

[0039]

Specifically, in the hot-dip plating layer of the embodiment, for incident light having an incident angle in a range of 0° to less than 90°, reflected light from the pattern part in the normal-line direction and reflected light from the non-pattern part in the normal-line direction have a relationship such that formula (1) and formula (2) below are satisfied. The incident angle of the incident light is an angle against the normal-line direction of the surface of the steel sheet. The pattern part and the non-pattern part, having a relationship such that formula (1) and formula (2) below are satisfied, are preferably a pattern part and a non-pattern part adjacent to each other with the boundary interposed therebetween.

[0040]

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1)$$

$$|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2)$$

[0041]

In formula (1) and formula (2), I_{PH} , I_{BH} , I_{PM} , I_{BM} , I_{PL} , and I_{BL} are as follows, respectively.

I_{PH} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°

5 I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°

I_{PM} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 35° to 80°

10 I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 35° to 80°

I_{PL} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°

I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90°

15 [0042]

I_{PH} , I_{BH} , I_{PM} , I_{BM} , I_{PL} , and I_{BL} will be described in detail with reference to FIGS. 1 (A) to (D).

FIG. 1 (A) is a diagram illustrating the incident angle of incident light, and shows a steel sheet surface S, a normal line H of the steel sheet surface, the range of an incident angle of 0 to less than 35° against the normal line H, the range of an incident angle of 35° to 80° , and the range of an incident angle of more than 80° to less than 90° , respectively.

[0043]

FIGS. 1 (B) to 1 (D) show the relationship between incident light and reflected light in the pattern part.

FIG. 1 (B) shows the reflection intensity I_{PH} . The reflection intensity I_{PH} is a reflection intensity from the pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of 0° to less than 35° . FIG. 1 (C) shows the reflection intensity I_{PM} . The reflection intensity I_{PM} is a reflection intensity from the pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of 35° to 80° . FIG. 1 (D) shows the reflection intensity I_{PL} . The reflection intensity I_{PL} is a reflection intensity from the pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° .

[0044]

FIGS. 1 (E) to 1 (G) show the relationship between incident light and reflected light in the non-pattern part.

FIG. 1 (E) shows the reflection intensity I_{BH} . The reflection intensity I_{BH} is a reflection intensity from the non-pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of 0° to less than 35° . FIG. 1 (F) shows the reflection intensity I_{BM} . The reflection intensity I_{BM} is a reflection intensity from the non-pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of 35° to 80° . FIG. 1 (D) shows the reflection intensity I_{BL} . The reflection intensity I_{BL} is a reflection intensity from the non-pattern part, and is a reflection intensity in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° .

[0045]

Next, formula (1) and formula (2) will be described with reference to FIG. 2.

Here, the relationship between $|I_{PM} - I_{BM}|$, $|I_{PH} - I_{BH}|$, and $|I_{PL} - I_{BL}|$ and the visibility of the pattern part will be described. FIG. 2 shows the relationship between incident light and

reflected light for each of the pattern part and the non-pattern part, and the intensity difference (contrast) of reflected light between the pattern part and the non-pattern part.

[0046]

$|I_{PM} - I_{BM}|$ is the intensity difference between the reflection intensity I_{PM} from the pattern part and the reflection intensity I_{BM} from the non-pattern part when incident light having an incident angle of 35° to 80° is incident. As the difference in reflection intensity becomes larger between the pattern part and the non-pattern part, that is, as $|I_{PM} - I_{BM}|$ becomes larger, the brightness of reflected light remarkably differs between the pattern part and the non-pattern part. Accordingly, the pattern part is easily visually recognized. Conversely, as $|I_{PM} - I_{BM}|$ becomes smaller, the brightness of reflected light becomes closer between the pattern part and the non-pattern part. Accordingly, the pattern part is less likely to be visually recognized. The same applies to $|I_{PH} - I_{BH}|$ and $|I_{PL} - I_{BL}|$. Specific examples will be described below.

[0047]

In FIG. 2, as an example of the case where the pattern part is easily visually recognized, the magnitude of the reflection intensity from the pattern part and the non-pattern part is visually illustrated for the case where incident light having an incident angle of 0 to 90° is incident. The length of the arrow in each diagram corresponds to the magnitude relationship in the reflection intensity and the intensity difference. FIG. 2 (A3), (B3), and (C3) show the intensity difference for each incident angle of incident light, and $|I_{PM} - I_{BM}|$ is larger than $|I_{PH} - I_{BH}|$ and $|I_{PL} - I_{BL}|$. This is because $|I_{PM} - I_{BM}|$ becomes relatively large when incident light is incident at an incident angle of 35 to 80° , and $|I_{PH} - I_{BH}|$ and $|I_{PL} - I_{BL}|$ become relatively small when incident light is incident at an incident angle other than 35 to 80° , so that the pattern part is easily visually recognized when incident light is incident at an incident angle of 35 to 80° .

[0048]

$|I_{PM} - I_{BM}|$ is the difference in reflection intensity between the pattern part and the non-pattern part when incident light having an incident angle of 35° to 80° is incident, $|I_{PH} - I_{BH}|$ is the difference in reflection intensity between the pattern part and the non-pattern part when incident light having an incident angle of 0° to less than 35° is incident, and $|I_{PL} - I_{BL}|$ is the difference in reflection intensity between the pattern part and the non-pattern part when incident light having an incident angle of more than 80° to less than 90° is incident. Therefore, the conditions in which the pattern part is easily visually recognized when incident light having an incident angle of 35° to 80° is incident are that $|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}|$ and $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}|$ are both less than 1.0, that is, the above formulae (1) and (2) are satisfied.

[0049]

As described above, when the above formulae (1) and (2) are satisfied, the pattern part is easily visually recognized when incident light is incident at an incident angle of 35 to 80° , and the pattern part is less likely to be visually recognized when incident light is incident at an incident angle of 0 to less than 35° and more than 80° to less than 90° .

[0050]

FIGS. 2 (A1), (A2), (B1), (B2), (C1), and (C2) will be described. FIGS. 2 (A1) and (A2) show the reflection intensity I_{PH} from the pattern part and the reflection intensity I_{BH} from the non-pattern part when incident light having an incident angle of 0° to less than 35° is incident. The length of the arrows corresponds to the magnitude of the reflection intensity. FIG. 2 (A3) shows $|I_{PH} - I_{BH}|$, the intensity difference between the reflection intensity I_{PH} from the pattern part and the reflection intensity I_{BH} from the non-pattern part.

FIGS. 2 (B1) and (B2) show the reflection intensity I_{PM} from the pattern part and the reflection intensity I_{BM} from the non-pattern part when incident light having an incident angle of 35° to 80° is incident. The length of the arrows corresponds to the magnitude of the reflection intensity. FIG. 2 (B3) shows $|I_{PH} - I_{BH}|$, the intensity difference between the reflection intensity I_{PM} from the pattern part and the reflection intensity I_{BM} from the non-pattern part.

FIGS. 2 (C1) and (C2) show the reflection intensity I_{PL} from the pattern part and the reflection intensity I_{BL} from the non-pattern part when the incident light having an incident angle of less than 80° to less than 90° is incident. The length of the arrows corresponds to the magnitude of the reflection intensity. FIG. 2 (C3) shows $|I_{PL} - I_{BL}|$, the intensity difference between the reflection intensity I_{PL} from the pattern part and the reflection intensity I_{BL} from the non-pattern part.

[0051]

As described above, the hot-dip plated steel sheet of the embodiment satisfies formula (1) and formula (2) at the same time. Thereby, the pattern part is easily visually recognized in the direction of the normal line H when incident light is incident at an incident angle of 35° to 80° . On the other hand, the pattern part is less likely to be visually recognized in the direction of the normal line H when incident light is incident at an incident angle other than 35° to 80° . As a result, when light is incident on the hot-dip plating layer from a direction of 35° to 80° , the pattern part can be distinguished in human vision, and when light is incident from other directions, the pattern part can be difficult to distinguish.

[0052]

In the hot-dip plating layer of the embodiment, the combination of the reflected light intensities from the pattern part and non-pattern part only satisfies formula (1) and

formula (2) at the same time, and is not limited to the relationship shown in FIG. 2.

The hot-dip plated steel sheet of the embodiment may have a chemical treatment film layer or a coating film layer on the surface of the hot-dip plating layer. Here, the type of chemical treatment film layer and coating film layer is not particularly limited, and known chemical treatment film layers and coating film layers can be used.

As an example of the chemical treatment film, a chemical treatment film including a phthalocyanine pigment coated with at least one of a resin and a surfactant can be exemplified. The hot-dip plating layer provided with such a chemical treatment film can impart a preferable design property to the surface of the plating layer and enhance the visibility of the pattern part when colored with a phthalocyanine pigment. Furthermore, the corrosion resistance, weather resistance, and the like of the chemical treatment film can be improved.

[0053]

The surface of the pattern part and the non-pattern part is preferably provided with minute inclined surfaces in order to satisfy formula (1) and formula (2). The region intended to have an enhanced reflected light intensity for incident light having an incident angle of 35° to 80° (hereinafter, referred to as high reflection region) is to be provided with many minute inclined surfaces having an inclination angle of 17° to 40° against the steel sheet surface. The minute inclined surfaces having an inclination angle of 17° to 40° desirably occupy 60% or more of the total area of the high reflection region.

The inclination angle is determined by measuring the surface shape of the pattern part. Examples of a device to measure the surface shape include a white light interference microscope (Contour GT I Elite, from Bruker). The ratio of the minute inclined surfaces having an inclination angle of 17° to 40° can be calculated using a white light interference microscope, for example, as follows: in a region of $500\text{ }\mu\text{m} \times 500$

μm or more in the surface of the pattern part, an inclination Δi is determined for each point; the inclination Δi is converted to a surface angle θ_i by the following formula (3); and the ratio of the region where the surface angle θ_i has an absolute value of 17° to 40° is calculated. Note that the inclination Δi is equal to a local inclination dZ_i/dX_i

5 calculated by the following formula (5), and thus can be obtained from the following formula (5).

[0054]

$$\theta_i = \tan^{-1} \Delta i \quad \dots \quad (3)$$

[0055]

10 When the surface shape is measured, the inclination angle is preferably calculated from the surface shape after its undulation component is removed through a high-pass filter with a cutoff value of 300 μm. Determination of the inclination angle is greatly affected by sampling interval. Therefore, in the present specification, the sampling interval is preferably 1 μm or more and 4 μm or less. This is because, with an

15 excessively small sampling interval, irregular high-frequency components in the noise may be picked up to estimate the surface angle to be excessively large, and with an excessively large sampling interval, the surface angle may be inaccurately estimated. The measurement area is preferably wide, and the measurement is preferably performed in a region of at least 500 μm × 500 μm or more.

20 In the minute inclined surfaces having an inclination angle of 17° to 40°, the roughness curve has a root mean square inclination $R\Delta q$ of 17° to 40°. The root mean square inclination $R\Delta q$ of the roughness curve is defined as the root mean square of the local inclination dZ_i/dX_i in JIS-B0601:2001, and is expressed by the following formula (4). $R\Delta q$ is an average value of inclination in the minute region.

25 The root mean square inclination $R\Delta q$ is determined by measuring the surface

shape of the pattern part similarly to the inclination angle. Examples of a device to measure the surface shape include a white light interference microscope (Contour GT I Elite, from Bruker).

[0056]

5 [Mathematical Formula 1]

$$R \Delta q = \sqrt{\frac{1}{n} \sum_i^n (dZ_i/dX_i)^2} \quad \dots (4)$$

In the above formula, "n" is the total of measurement points and dZ_i/dX_i means a local inclination for an order of "i". The local inclination at each point in the measurement surface is determined by, for example, the following formula (5).

10 [0057]

[Mathematical Formula 2]

$$dZ_i/dX_i = \frac{Z_{i+1} - Z_{i-1}}{2 \Delta X} \quad \dots (5)$$

In the formula, when one direction is defined as the X direction in the measurement surface, X_i is a position for an order of "i" in the X direction, Z_i is a height for an order of "i", and ΔX is a sampling interval.

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[0058]

On the other hand, the region intended to have a reduced reflected light intensity for incident light having an incident angle of 35° to 80° (hereinafter, referred to as low reflection region) is to be provided with many minute inclined surfaces having an inclination angle of less than 17° or more than 40° against the steel sheet surface. The minute inclined surfaces having an inclination angle of less than 17° or more than 40° desirably occupy 60% or more of the total area of the low reflection region. That is, the

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low reflection region has a small number of minute inclined surfaces having an inclination angle of 17° to 30° against the steel sheet surface. In the low reflection region, the area ratio of the minute inclined surface having an inclination angle of 17° to 40° desirably occupies 40% or less of the total area of the low reflection region. The ratio of the minute inclined surfaces having an inclination angle of less than 17° or more than 40° can be calculated, as described above, from formulae (3) to (5) after the inclination Δi is determined for each point in a region of $500\ \mu\text{m} \times 500\ \mu\text{m}$ or more in the surface of the pattern part.

[0059]

10 In the measurement of the reflection intensities I_{PH} , I_{BH} , I_{PM} , I_{BM} , I_{PL} , and I_{BL} , first, the surface of the plating layer is photographed with a digital optical camera to obtain imaging data. In photographing with a digital optical camera, the surface of the plating layer is photographed in its perpendicular direction. At this time, light having an incident angle of more than 0° to less than 35° , light having an incident angle of 35° to 80° , and light having an incident angle of more than 80° to less than 90° are incident as photographing light to photograph for each incident angle. It is desirable to make a difference of 10° or more between the incident angles. The photographing is desirably performed in an environment in which light other than the photographing light can be shielded. Light intensity data at each pixel in the imaging data is extracted from the obtained imaging data. Since the imaging data may vary depending on individual differences of the digital optical camera, histogram correction may be performed so that the brightness of the image matches the case of visual observation. In general, since the light intensity data of each pixel is represented by 256 gradation shading data in which 0 is black and 255 is white, this data is extracted. Then, the average value of the brightness of the pixels included in the pattern part is defined as the reflection intensities

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I_{PH} , I_{PM} , and I_{PL} . The average value of the brightness of the pixels included in the non-pattern part is defined as the reflection intensities I_{BH} , I_{BM} , and I_{BL} . From these reflection intensities, values of $|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}|$ and $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}|$ are determined.

5 [0060]

[Method for producing hot-dip plated steel sheet]

Next, the method for producing the hot-dip plated steel sheet of the embodiment will be described.

In the hot-dip plated steel sheet of the embodiment, a steel sheet manufactured
10 through steelmaking, casting, and hot rolling is hot-dip plated. Further, after the hot rolling, pickling, hot-rolled sheet annealing, cold rolling, and cold-rolled sheet annealing may be further performed, and then hot-dip plating may be performed. The hot-dip plating is a continuous hot-dip plating method in which a steel sheet is continuously passed through a hot-dip plating bath.

15 [0061]

The hot-dip plating bath preferably includes 4 to 22 mass% of Al and 1.0 to 10 mass% of Mg, and includes Zn and impurities as a balance. The hot-dip plating bath may include 4 to 22 mass% of Al and 1.0 to 10 mass% of Mg, and may include a balance consisting of Zn and impurities. The hot-dip plating bath may include 0.0001 to 2
20 mass% of Si, and may include 0.0001 to 2 mass% in total of at least one of Ni, Ti, Zr, Sr, Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf, and C.

[0062]

The temperature of the hot-dip plating bath varies depending on the composition, but is preferably, for example, in a range of 400 to 500°C. This is because
25 a desired hot-dip plating layer can be formed when the hot-dip plating bath has a

temperature in this range.

The adhesion amount of the hot-dip plating layer may be adjusted by means such as gas wiping on the steel sheet pulled up from the hot-dip plating bath. The adhesion amount of the hot-dip plating layer is preferably adjusted so that the total
5 adhesion amount of both surfaces of the steel sheet falls within a range of 30 to 600 g/m². When the adhesion amount is less than 30 g/m², the corrosion resistance of the hot-dip plated steel sheet is deteriorated, which is not preferable. When the adhesion amount exceeds 600 g/m², molten metal adhering to the steel sheet sags, and the surface of the hot-dip plating layer cannot be smoothed, which is not preferable.

10 [0063]

After the hot-dip plating layer is formed, the pattern part and the non-pattern part are formed. The pattern part and the non-pattern part are formed by providing minute inclined surfaces at a position where the pattern part and the non-pattern part are to be formed in the surface of the plating layer.

15 [0064]

The region intended to have an enhanced reflected light intensity for incident light having an incident angle of 35° to 80° is to be provided with many minute inclined surfaces having an inclination angle of 17° to 40° against the steel sheet surface. The minute inclined surfaces having an inclination angle of 17° to 40° desirably occupy 60%
20 or more of the total area of this region.

[0065]

On the other hand, the region intended to have a reduced reflected light intensity for incident light having an incident angle of 35° to 80° is to be provided with many minute inclined surfaces having an inclination angle of less than 17° or more than 40°
25 against the steel sheet surface. The minute inclined surfaces having an inclination angle

of less than 17° or more than 40° desirably occupy 60% or more of the total area of this region.

[0066]

The minute inclined surface as described above is formed by roll forming.

- 5 That is, the surface shape of the roll surface is adjusted so that inclined surfaces having the above-described inclination angle can be formed, the roll is pressed against the surface of the hot-dip plating layer, and the surface shape of the roll is transferred to the hot-dip plating layer.

[0067]

- 10 The transferring is preferably performed when the hot-dip plating layer has a surface temperature in a range of 250 to 300°C. When the surface temperature of the hot-dip plating layer is less than 250°C during roll transfer, the hot-dip plating layer is not softened, making it difficult to form a clear pattern part, which is not preferable.
- When the surface temperature of the hot-dip plating layer exceeds 300°C, roll transfer is
- 15 performed in a state where the hot-dip plating layer is significantly softened, and there is a possibility that the pattern part and the non-pattern part cannot be clearly distinguished, which is not preferable.

[0068]

- Further, when a chemical treatment layer is formed on the surface of the hot-dip
- 20 plating layer, the hot-dip plated steel sheet after the hot-dip plating layer is formed is subjected to chemical treatment. Here, the type of the chemical treatment is not particularly limited, and a known chemical treatment can be used.

- When a coating film layer is formed on the surface of the hot-dip plating layer or the surface of the chemical treatment layer, coating treatment is performed on the hot-dip
- 25 plated steel sheet after the hot-dip plating layer is formed or after the chemical treatment

layer is formed. The type of the coating treatment is not particularly limited, and a known coating treatment can be used.

[0069]

As an example of the chemical treatment, a chemical treatment using a chemical treatment agent including a phthalocyanine pigment coated with at least one of a resin and a surfactant can be exemplified. Specific examples of the chemical treatment agent that can be used include an aqueous coating agent including: a polyurethane resin particle and an ethylene-unsaturated carboxylic acid copolymer resin particle each having at least one of a silanol group and an alkoxyethyl group; a silicon oxide particle; an organic titanium compound; and the phthalocyanine pigment, where the content of the phthalocyanine pigment is 0.01 to 10 parts by mass with respect to 100 parts by mass of the total of the polyurethane resin particle and the ethylene-unsaturated carboxylic acid copolymer resin particle, and the phthalocyanine pigment has a primary particle diameter of 0.01 to 1.0 μm . The hot-dip plating layer subjected to such a chemical treatment can impart a preferable design property to the surface of the plating layer and further enhance the corrosion resistance, weather resistance, and the like of the formed chemical treatment film when colored with a phthalocyanine pigment.

[0070]

According to the embodiment, the pattern such as characters and designs shown in the surface of the plating layer can be distinguished by human vision when light is incident from a specific direction, and the pattern can be difficult to distinguish when light is incident from other directions. In addition, in the embodiment, a roll having an adjusted surface shape is pressed against the surface of the hot-dip plating layer to transfer the surface shape of the roll to the hot-dip plating layer. Thereby, the range of the pattern part or the non-pattern part can be provided with an intentional or artificial

shape, and the pattern part can be arranged in a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a dot portion, a figure, a number, a symbol, and a character. As a result, various designs, trademarks, and other identification marks can be represented on the surface of the hot-dip plating layer without printing or painting, and the distinguishability of the source of the steel sheet, the designability, and the like can be improved. In addition, with the pattern part, the hot-dip plated steel sheet can be provided with information necessary for process management, inventory management, and the like and arbitrary information required by the consumer. This can also contribute to improvement in productivity of the hot-dip plated steel sheet.

Conventionally, when characters, designs, and the like are shown on the surface of the plating layer by stamping an ink, cost and time are relatively suppressed, but the reactivity between the ink and the hot-dip plating layer needs to be considered. Furthermore, when a design or the like is shown by grinding the hot-dip plating layer, the design or the like has excellent durability, but the thickness of the ground hot-dip plating layer needs to be considered.

Examples

[0071]

Next, Examples of the present invention will be described. The steel sheet was degreased and washed with water, and then subjected to reduction annealing, plating bath immersion, adhesion amount control, and cooling to produce the hot-dip plated steel sheets of Nos.1 to 47 shown in Tables 2A to 3B. Subsequently, in a state where the surface temperature of the hot-dip plating layer was 250 to 300°C, rolls A to F having a square pattern with a side of 50 mm were pressed against the surface of the hot-dip plating layer to form the pattern part. Details of the rolls A to F having a square pattern

are shown in Table 1. The portion of the square pattern was defined as the pattern part, and the portion other than the square pattern was defined as the non-pattern part. When the ratio of the minute inclined surface in the surface of the pattern part and the non-pattern part was measured by the above-described method, it was consistent with the results in Table 1.

[0072]

[Table 1]

Roll	Pattern part	Non-pattern part
A	In surface irregularities, 80% of inclination was 17 to 30°	In surface irregularities, 90% or more of inclination was 0 to 5°
B	In surface irregularities, 80% of inclination was 30 to 40°	In surface irregularities, 90% or more of inclination was 0 to 5°
C	In surface irregularities, 80% of inclination was 30 to 40°	In surface irregularities, 60% of inclination was 0 to 15°
D	In surface irregularities, 60% of inclination was 17 to 30°	In surface irregularities, 90% or more of inclination was 0 to 5°
E	In surface irregularities, 80% of inclination was 40 to 45°	In surface irregularities, 90% or more of inclination was 0 to 5°
F	In surface irregularities, 40% of inclination was 17 to 30°	In surface irregularities, 90% or more of inclination was 0 to 5°

[0073]

10 In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was produced in the same manner as described above. Thereafter, a square pattern having a side of 50 mm was printed on the surface of the hot-dip plating layer by an inkjet method. The results are shown in Table 2B and Table 3B as No. 48.

[0074]

15 In addition, a Zn-Al-Mg-based hot-dip plated steel sheet was produced in the same manner as described above. Thereafter, the surface of the hot-dip plating layer was ground to form a square pattern having a side of 50 mm. The results are shown in Table 2B and Table 3B as No. 49.

[0075]

For the obtained hot-dip plated steel sheet, $|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}|$ and $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}|$ were determined. Specifically, the surface of the plating layer of the plated steel sheet was photographed with a digital optical camera to obtain imaging data. In

5 photographing with a digital optical camera, the surface of the plating layer was photographed in its perpendicular direction. At this time, light having an incident angle of more than 0° to less than 35° , light having an incident angle of 35 to 80° , and light having an incident angle of more than 80° to less than 90° were incident as

photographing light to photograph for each incident angle. A difference of 10° or more

10 was made between the incident angles. Light intensity data at each pixel was extracted from the obtained imaging data. In general, since the light intensity data of each pixel is represented by 256 gradation shading data in which 0 is black and 255 is white, this data was extracted. Then, the average value of the light intensity of the pixels included in the pattern part was defined as the reflection intensities I_{PH} , I_{BH} , I_{PM} , I_{BM} , I_{PL} and I_{BL} .

15 From these reflection intensities, values of $|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}|$ and $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}|$ were determined.

[0076]

In an example in which it was difficult to determine the boundary between the pattern part and the non-pattern part, the values of $|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}|$ and $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}|$ were determined assuming that the portion corresponding to the square pattern on

20 the roll surface was the pattern part.

[0077]

[Distinguishability]

The test plate provided with a square pattern part, in an initial state immediately

25 after production, was visually evaluated based on the following criteria. In the initial

state, the distinguishability was evaluated when light having incident angles of more than 0° to less than 35°, 35 to 80°, and more than 80° to less than 90° was incident as the light incident direction in observation, and the plating surface was visually checked from the normal-line direction. A (Excellent) to C (Mediocre) were regarded as acceptable.

5 [0078]

A (Excellent): Almost invisible for light with an incident angle of 0 to less than 35° and more than 80° to less than 90°, but well visible for light with an incident angle of 35 to 80°.

10 B (Good): Hardly visible for light with an incident angle of 0 to less than 35° and more than 80° to less than 90°, but visible for light with an incident angle of 35 to 80°.

C (Mediocre): Hardly visible for light with any incident angle, but barely visible for light with an incident angle of 35 to 80°.

15 D (Bad): Not visible for light with any incident angle, or visible for light with any incident angle.

[0079]

[Corrosion resistance]

The test plate was cut into 150 × 70 mm, and subjected to a corrosion acceleration test CCT in accordance with JASO-M609 for 30 cycles. Thereafter, the rust generation state was investigated and evaluated based on the following criteria. A (Excellent) to C (Mediocre) were regarded as acceptable.

A (Excellent): No rust was generated and an aesthetically pleasing design appearance was maintained.

25 B (Good): No rust was generated, but a slight change in appearance was observed.

C (Mediocre): No rust was generated, but a certain degree of change in appearance was observed.

D (Bad): The pattern part and the non-pattern part were significantly deteriorated in appearance quality, and could not be visually distinguished.

5 [0080]

As shown in Tables 2A to 3B, the Zn-Al-Mg-based hot-dip plated steel sheets of Examples of the present invention, No. 1 to No. 41, had both excellent distinguishability and corrosion resistance. However, in No. 40 and No. 41, distinguishability slightly deteriorated compared with other examples.

10 [0081]

On the other hand, as shown in Tables 2B and 3B, in No. 42, the Al content was insufficient in the average composition of the hot-dip plating layer. For this reason, the corrosion resistance of the hot-dip plating layer was insufficient.

In No. 43, the Al content was excessive in the average composition of the hot-dip plating layer. For this reason, the corrosion resistance of the hot-dip plating layer was insufficient.

[0082]

In No. 44, the Mg content was insufficient in the average composition of the hot-dip plating layer. For this reason, the corrosion resistance of the hot-dip plating layer was insufficient.

In No. 45, the Mg content was excessive in the average composition of the hot-dip plating layer. For this reason, dross occurred in the plating bath, and the corrosion resistance of the hot-dip plating layer was insufficient.

[0083]

25 In No. 46 and No. 47, since the shape of the roll surface was inappropriate, the

conditions of formula (1) and formula (2) were not satisfied, and the distinguishability was poor.

[0084]

In No. 48, in which a square pattern part was printed by an inkjet method, the
5 pattern part was thinned due to outdoor exposure for 6 months, and the distinguishability was deteriorated.

No. 49, in which a square pattern was formed by grinding, was evaluated as no
problem based on the evaluation criteria for corrosion resistance. However, the
thickness of the plating layer was reduced at the ground positions, and therefore, the
10 corrosion resistance at the ground positions was locally reduced and the appearance was not preferable.

The plating layers of Nos. 1 to 41 and 46 to 49 contained an Al phase and an
Al/Zn/MgZn₂ ternary eutectic structure.

[0085]

15 Further, a chemical treatment film was formed on the surface of the plating layer of Nos. 38 to 41, and the designability was checked. The chemical treatment film was formed by chemical treatment with a chemical treatment agent including a phthalocyanine pigment. The chemical treatment agent used was an aqueous coating agent including: a polyurethane resin particle and an ethylene-unsaturated carboxylic
20 acid copolymer resin particle having a silanol group and an alkoxysilyl group; a silicon oxide particle; an organic titanium compound; and a Cu phthalocyanine, where the content of the Cu phthalocyanine pigment was 0.01 to 10 parts by mass with respect to 100 parts by mass of the total of the polyurethane resin particle and the ethylene-unsaturated carboxylic acid copolymer resin particle, and the Cu phthalocyanine had a
25 primary particle diameter of 0.01 to 1.0 μm .

[0086]

The distinguishability was evaluated for Nos. 38 to 41, on which the chemical treatment film was formed. All of them were evaluated as “A (Excellent)”, and the distinguishability was further improved by the provided chemical treatment film

5 including a Cu phthalocyanine.

[0087]

[Table 2A]

No.	Production method		Hot-dip plating layer				
	Production method	Roll used	Average composition (mass%) Balance: Zn and impurities				Adhesion amount of plating on both surfaces (g/m ²)
			Al	Mg	Si	Others	
1	Roll transfer	A	4	3.0	-	Ni 0.01%	30
2	Roll transfer	B	6	3.0	0.2	Ti 0.01%	300
3	Roll transfer	B	11	3.0	0.2	Ti 0.01%	340
4	Roll transfer	B	19	6.0	0.2	Ni 0.01%	320
5	Roll transfer	A	22	6.0	0.2	Ti 0.01%	350
6	Roll transfer	A	11	1.0	-	-	300
7	Roll transfer	B	11	1.5	-	-	320
8	Roll transfer	B	11	2.0	0.2	-	340
9	Roll transfer	B	11	6.0	0.2	-	320
10	Roll transfer	A	11	8.0	0.2	-	320
11	Roll transfer	A	11	10	0.2	-	330
12	Roll transfer	B	11	3.0	0.0001	-	300
13	Roll transfer	B	11	3.0	0.01	-	300
14	Roll transfer	B	11	3.0	0.03	-	300
15	Roll transfer	B	11	3.0	0.08	-	290
16	Roll transfer	A	11	3.0	1	-	340
17	Roll transfer	B	11	3.0	2	-	280
18	Roll transfer	A	11	3.0	0.2	Ti 0.01%	340
19	Roll transfer	B	11	3.0	0.2	Ni 0.01%	300
20	Roll transfer	A	11	3.0	0.2	Zr 0.01%	320
21	Roll transfer	B	11	3.0	0.2	Ni 0.01%	300
22	Roll transfer	B	11	3.0	0.2	Sr 0.01%	310
23	Roll transfer	A	11	3.0	0.2	Fe 0.01%	330

10 [0088]

[Table 2B]

No.	Production method		Hot-dip plating layer				
	Production method	Roll used	Average composition (mass%) Balance: Zn and impurities				Adhesion amount of plating on both surfaces (g/m ²)
			Al	Mg	Si	Others	
24	Roll transfer	B	11	3.0	0.2	Sb 0.01%	350
25	Roll transfer	A	11	3.0	0.2	Pb 0.01%	600
26	Roll transfer	B	11	3.0	0.2	Sn 0.01%	320
27	Roll transfer	B	11	3.0	0.2	Ca 0.01%	300
28	Roll transfer	A	11	3.0	0.2	Co 0.01%	340
29	Roll transfer	A	11	3.0	0.2	Mn 0.01%	280
30	Roll transfer	B	11	3.0	0.2	P 0.01%	330
31	Roll transfer	B	11	3.0	0.2	B 0.01%	330
32	Roll transfer	B	11	3.0	0.2	Bi 0.01%	290
33	Roll transfer	B	11	3.0	0.2	Cr 0.01%	320
34	Roll transfer	B	11	3.0	0.2	Sc 0.01%	330
35	Roll transfer	B	11	3.0	0.2	Y 0.01%	310
36	Roll transfer	B	11	3.0	0.2	REM 0.01%	340
37	Roll transfer	B	11	3.0	0.2	Hf 0.01%	340
38	Roll transfer	B	11	3.0	0.2	C 0.01%	350
39	Roll transfer	B	11	3.0	0.2	Ti 0.01% Ca 0.01%	320
40	Roll transfer	C	11	3.0	0.2	-	330
41	Roll transfer	D	11	3.0	0.2	-	350
42	Roll transfer	B	<u>3</u>	3.0	0.2	-	320
43	Roll transfer	B	<u>23</u>	3.0	0.2	-	300
44	Roll transfer	A	11	<u>0.5</u>	0.2	-	280
45	Roll transfer	A	11	<u>11</u>	0.2	-	280
46	Roll transfer	E	11	3.0	0.2	-	350
47	Roll transfer	F	11	3.0	0.2	-	320
48	Printing after plating	-	11	3.0	0.2	-	280
49	Grinding after plating	-	11	3.0	0.2	-	290

Underlines indicate that it is out of the scope of the present invention.

[0089]

[Table 3A]

No.	Hot-dip plating layer		Distinguish ability	Corrosion resistance	Note
	Formula (1)	Formula (2)			
	$ I_{PH}-I_{BH} / I_{PM}-I_{BM} $	$ I_{PL}-I_{BL} / I_{PM}-I_{BM} $			
1	0.3	0.2	A	C	Example
2	0.4	0.5	A	A	Example
3	0.6	0.5	A	A	Example
4	0.2	0.6	A	A	Example
5	0.2	0.3	A	C	Example
6	0.2	0.2	A	C	Example

7	0.2	0.2	A	B	Example
8	0.5	0.6	A	A	Example
9	0.2	0.6	A	A	Example
10	0.6	0.3	A	A	Example
11	0.6	0.4	A	C	Example
12	0.5	0.5	A	A	Example
13	0.6	0.2	A	A	Example
14	0.2	0.6	A	A	Example
15	0.3	0.5	A	A	Example
16	0.5	0.5	A	A	Example
17	0.4	0.6	A	A	Example
18	0.6	0.6	A	A	Example
19	0.4	0.4	A	A	Example
20	0.3	0.5	A	A	Example
21	0.6	0.6	A	A	Example
22	0.2	0.5	A	A	Example
23	0.3	0.2	A	A	Example

[0090]

[Table 3B]

No.	Hot-dip plating layer		Distinguish ability	Corrosion resistance	Note
	Formula (1)	Formula (2)			
	$ I_{PH}-I_{BH} / I_{PM}-I_{BM} $	$ I_{PL}-I_{BL} / I_{PM}-I_{BM} $			
24	0.3	0.4	A	A	Example
25	0.2	0.5	A	A	Example
26	0.2	0.5	A	A	Example
27	0.6	0.3	A	A	Example
28	0.4	0.6	A	A	Example
29	0.5	0.3	A	A	Example
30	0.3	0.2	A	A	Example
31	0.3	0.6	A	A	Example
32	0.2	0.5	A	A	Example
33	0.6	0.6	A	A	Example
34	0.6	0.4	A	A	Example
35	0.5	0.3	A	A	Example
36	0.4	0.6	A	A	Example
37	0.4	0.3	A	A	Example
38	0.2	0.5	A	A	Example
39	0.4	0.6	A	A	Example
40	0.7	0.8	B	A	Example
41	0.9	0.9	C	A	Example
42	0.4	0.4	A	D	Comparative Example
43	0.4	0.6	A	D	Comparative Example
44	0.5	0.3	A	D	Comparative Example
45	0.2	0.2	A	D	Comparative

					Example
46	<u>3.0</u>	<u>4.0</u>	D	A	Comparative Example
47	<u>1.0</u>	<u>1.1</u>	D	A	Comparative Example
48	<u>1.0</u>	<u>1.5</u>	D	A	Comparative Example
49	<u>2.0</u>	<u>1.3</u>	D	A	Comparative Example

Underlines indicate that it is out of the scope of the present invention.

CLAIMS

[Claim 1] A hot-dip plated steel sheet, comprising: a steel sheet; and a hot-dip plating layer formed on a surface of the steel sheet, wherein

the hot-dip plating layer includes, as an average composition, 4 to 22 mass% of
5 Al and 1.0 to 10 mass% of Mg, and includes a balance including Zn and impurities,
the hot-dip plating layer includes a pattern part and a non-pattern part, and
for incident light having an incident angle in a range of 0° to less than 90°
against a normal-line direction of the surface of the steel sheet, reflected light from the
pattern part in the normal-line direction and reflected light from the non-pattern part in
10 the normal-line direction have a relationship such that formula (1) and formula (2) below
are satisfied:

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1), \text{ and}$$

$$|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2),$$

herein,

15 I_{PH} : reflection intensity from the pattern part in the normal-line direction for
incident light having an incident angle of 0° to less than 35°,

I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for
incident light having an incident angle of 0° to less than 35°,

I_{PM} : reflection intensity from the pattern part in the normal-line direction for
20 incident light having an incident angle of 35° to 80°,

I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for
incident light having an incident angle of 35° to 80°,

I_{PL} : reflection intensity from the pattern part in the normal-line direction for
incident light having an incident angle of more than 80° to less than 90°, and

25 I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for

incident light having an incident angle of more than 80° to less than 90°.

[Claim 2] A hot-dip plated steel sheet, comprising: a steel sheet; and a hot-dip plating layer formed on a surface of the steel sheet, wherein

the hot-dip plating layer includes, as an average composition, 4 to 22 mass% of
5 Al and 1.0 to 10 mass% of Mg, and includes a balance including Zn and impurities, and further includes one or two selected from a group consisting of the following group A and group B,

the hot-dip plating layer includes a pattern part and a non-pattern part, and

for incident light having an incident angle in a range of 0° to less than 90°

10 against a normal-line direction of the surface of the steel sheet, reflected light from the pattern part in the normal-line direction and reflected light from the non-pattern part in the normal-line direction have a relationship such that formula (1) and formula (2) below are satisfied:

$$|I_{PH} - I_{BH}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (1),$$

15 $|I_{PL} - I_{BL}|/|I_{PM} - I_{BM}| < 1.0 \quad \dots \quad (2),$

[Group A] 0.0001 to 2 mass% of Si, and

[Group B] 0.0001 to 2 mass% in total of at least one of Ni, Ti, Zr, Sr, Fe, Sb, Pb,

Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, Hf, and C,

herein,

20 I_{PH} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°,

I_{BH} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 0° to less than 35°,

I_{PM} : reflection intensity from the pattern part in the normal-line direction for
25 incident light having an incident angle of 35° to 80°,

I_{BM} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of 35° to 80° ,

I_{PL} : reflection intensity from the pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° , and

5 I_{BL} : reflection intensity from the non-pattern part in the normal-line direction for incident light having an incident angle of more than 80° to less than 90° .

[Claim 3] The hot-dip plated steel sheet according to claim 1 or 2, wherein the pattern part is arranged in a shape that is any one, or a combination of two or more, of a straight portion, a curved portion, a dot portion, a figure, a number, a symbol, and a character.

10 [Claim 4] The hot-dip plated steel sheet according to claim 1 or 2, wherein an adhesion amount of the hot-dip plating layer is 30 to 600 g/m^2 in total of both surfaces of the steel sheet.

[Claim 5] The hot-dip plated steel sheet according to claim 3, wherein an adhesion amount of the hot-dip plating layer is 30 to 600 g/m^2 in total of both surfaces of the steel
15 sheet.

[Claim 6] The hot-dip plated steel sheet according to claim 2, wherein the hot-dip plating layer has an average composition including the group A in terms of mass%.

[Claim 7] The hot-dip plated steel sheet according to claim 2, wherein the hot-dip plating layer has an average composition including the group B in terms of mass%.

20 [Claim 8] The hot-dip plated steel sheet according to claim 1 or 2, wherein, in the pattern part, a ratio of an inclined surface having an inclination angle of 17 to 40° is 60% or more.