

[Document Type] Specification

[Title of the Invention]

HOT-DIP PLATED STEEL SHEET

[Technical Field]

5 [0001]

The present invention relates to a hot-dip plated steel sheet, and specifically, to a hot-dip plated steel sheet having favorable appearance pattern uniformity. Priority is claimed on Japanese Patent Application No. 2020-061205, filed March 30, 2020, the content of which is incorporated herein by reference.

10 [Background Art]

[0002]

Hot-dip plated steel sheets are used as steel sheets having favorable corrosion resistance. Galvanizing steel sheets, which are typical examples of hot-dip plated steel sheets, are widely used in various manufacturing industry fields such as automobiles,
15 home appliances, and building materials.

[0003]

As a method of producing a galvanized steel sheet, a production method using a cold-rolled steel sheet or a hot-rolled steel sheet as a base steel sheet, and passing it through a continuous hot-dip galvanizing line (hereinafter referred to as CGL) is a usual
20 method. As a CGL process, a total reduction furnace method in which, in a cleaning section on the entry side, a base steel sheet is degreased by alkaline spray and then cleaned with a brush, and in an annealing section, annealing is performed in a reducing atmosphere and immersion in a hot dip galvanizing bath is then performed is generally used. In addition, a Sendzimir method in which a non-oxidizing furnace is provided at a
25 stage previous to an annealing section, and a base steel sheet whose surface is cleaned is

pre-heated in the non-oxidizing furnace and then reduced and annealed in a reduction furnace, and then immersed in a hot dip galvanizing bath may be used.

[0004]

In order to further improve the corrosion resistance of the galvanized steel sheet produced in the above process, a galvanized steel sheet having high corrosion resistance in which a galvanizing layer contains Al or Mg has been proposed. For example, Patent Document 1 proposes a Zn-Al-Mg-based hot-dip plated steel sheet. In addition, Patent Document 1 states that a hot-dip plated steel sheet having better corrosion resistance is obtained when a Zn-Al-Mg-based hot-dip plated steel sheet contains one or more of Ca, Be, Ti, Cu, Ni, Co, Cr, and Mn.

[0005]

Incidentally, the Zn-Al-Mg-based hot-dip plated steel sheet mainly contains the 4 types of phases and structures of [Al phase], [Zn phase], [MgZn₂ phase], and [ternary eutectic structure of Al/MgZn₂/Zn] in a hot-dip plated layer. In addition, when the hot-dip plated layer contains Si in addition to Zn, Al, and Mg, it is mainly composed of 5 types of phases and structures including [Mg₂Si phase] in addition to the above 4 types of phases and structures. Among these, the [Al phase] exhibits a white color when it appears on the surface of the plating layer, and the [ternary eutectic structure of Al/MgZn₂/Zn] exhibits a metallic luster. Since the [Al phase] and the [ternary eutectic structure of Al/MgZn₂/Zn] are present on the surface of the plating layer in a mixed manner, the surface of the hot-dip plated layer has a satin-like appearance.

[0006]

The satin-like appearance of the hot-dip plated layer is affected by the size of the [Al phase] and the size of the [ternary eutectic structure of Al/MgZn₂/Zn]. If the sizes of these phases and structures are substantially uniform over the entire surface of the hot-

dip plated layer, the overall appearance pattern uniformity is improved. However, a hot-dip plated layer of a conventional Zn-Al-Mg-based hot-dip plated steel sheet is not sufficient to satisfy having appearance pattern uniformity.

[0007]

5 Patent Document 2 states that the surface appearance is improved by adding Ti, B, and Si to the hot-dip Zn-Al-Mg plated steel sheet, but having appearance pattern uniformity is not sufficiently satisfied.

[Citation List]

[Patent Document]

10 [0008]

[Patent Document 1]

PCT International Publication No. WO 2000/071773

[Patent Document 2]

Japanese Unexamined Patent Application, First Publication No. 2001-295015]

15 [Summary of the Invention]

[Problems to be Solved by the Invention]

[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 having favorable
20 appearance pattern uniformity and excellent corrosion resistance.

[Means for Solving the Problem]

[0010]

In order to address the above problem, the present invention uses the following configurations.

25 [1] A hot-dip plated steel sheet including a steel sheet and a hot-dip plated layer

formed on a surface of the steel sheet,

wherein the hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with a remainder including Zn and impurities,

wherein, when five square measurement areas with sides of 5 mm are selected
5 from the surface of the hot-dip plated layer and intensity ratios A of each measurement area is obtained by a following measurement method, a ratio (A/A_{ave}) of an intensity ratio A of each measurement area to an average value A_{ave} of the intensity ratios A of the five measurement areas is in a range of 0.70 or more and less than 1.40, and

wherein the measurement method is a method in which each measurement area
10 is extracted as 256 level grayscale image data with a size of 50 pixels×50 pixels, a two-dimensional discrete Fourier transform is performed on the 256 gradation image data to obtain amplitude spectrum images of spatial frequencies, and in the obtained amplitude spectrum images, a sum S_{25} of intensities of spatial frequencies 1 to 25 and a sum S_5 of intensities of spatial frequencies 1 to 5 are calculated, and a ratio (S_5/S_{25}) of the
15 intensity sum S_5 to the intensity sum S_{25} is defined as an intensity ratio A .

[2] The hot-dip plated steel sheet according to [1], wherein the hot-dip plated layer has an average composition containing Al: 4 to 22 mass% and Mg: 1.0 to 10 mass%.

[3] The hot-dip plated steel sheet according to [1] or [2], wherein the hot-dip
20 plated layer further contains Si: 0.0001 to 2 mass% in the average composition.

[4] The hot-dip plated steel sheet according to any one of [1] to [3], wherein the hot-dip plated layer further contains a total of 0.0001 to 2 mass% of one or more of a group consisting of Ni, Ti, Zr, and Sr in the average composition.

[5] The hot-dip plated steel sheet according to any one of [1] to [4], wherein the
25 hot-dip plated layer further contains a total of 0.0001 to 2 mass% of one or more of a

group consisting of Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, and Hf in the average composition.

[6] The hot-dip plated steel sheet according to any one of [1] to [5], wherein an adhesion amount of the hot-dip plated layer is a total of 30 to 600 g/m² on both sides of the steel sheet.

[Effects of the Invention]

[0011]

According to the present invention, it is possible to provide a hot-dip plated steel sheet having favorable appearance pattern uniformity and excellent corrosion resistance.

[Brief Description of Drawings]

[0012]

Fig. 1 is a diagram showing a typical cross-sectional SEM observation image of a hot-dip plated steel sheet having a hot-dip plated layer having an average composition containing Al: 11 mass%, Mg: 3 mass%, Si: 0.2 mass%, with the remainder including Zn and impurities.

Fig. 2 is a diagram showing an example of 256 level grayscale image data in a measurement area and an example of an amplitude spectrum image of a spatial frequency obtained by performing a two-dimensional discrete Fourier transform on the gradation image data.

Fig. 3 is a diagram showing 256 level grayscale image data items in measurement areas and amplitude spectrum images of spatial frequencies obtained by performing a two-dimensional discrete Fourier transform on the gradation image data items.

Fig. 4 is a schematic diagram showing an example of a hot-dip plating facility for a hot-dip plated steel sheet of the present embodiment.

[Embodiment(s) for implementing the Invention]

[0013]

A hot-dip plated layer having an average composition containing Al: 2 to 22 mass% and Mg: 0.1 to 10 mass% is mainly composed of the 4 types of phases and structures of [Al phase], [MgZn₂ phase], [Zn phase], and [ternary eutectic structure of Al/MgZn₂/Zn]. In addition, when the hot-dip plated layer contains Si in addition to Zn, Al, and Mg, it is mainly composed of 5 types of phases and structures including [Mg₂Si phase] in addition to the above 4 types of phases and structures.

[0014]

The [Al phase] exhibits a white color when it appears on the surface of the plating layer, and the [ternary eutectic structure of Al/MgZn₂/Zn] exhibits a metallic luster. Since the [Al phase] and the [ternary eutectic structure of Al/MgZn₂/Zn] are present on the surface of the plating layer in a mixed manner, the surface of the hot-dip plated layer has a satin-like appearance. Thus, the satin-like appearance of the hot-dip plated layer is affected by the size of the [Al phase] and the size of the [ternary eutectic structure of Al/MgZn₂/Zn]. If the sizes of these phases and structures are substantially uniform over the entire surface of the hot-dip plated layer, the overall appearance pattern uniformity is improved.

[0015]

Here, the appearance pattern uniformity means that the appearance pattern appearing on the plating surface is uniform. The appearance pattern may be a satin pattern as long as the satin pattern is uniform. On the other hand, when spots or the like are partially observed on the plating surface, the appearance pattern uniformity is not satisfied.

[0016]

Incidentally, the steel sheet that has been immersed in the hot-dip plating bath and then pulled up is cooled by a method such as forced-air cooling after the adhesion amount of the plating layer is adjusted by a wiping nozzle. The inventors conducted extensive studies, and found that, when the steel sheet irregularly vibrates during forced-
5 air cooling in which a non-oxidizing gas is blown from the nozzle, the cooling speed partially changes on the surface of the steel sheet, the structure of the hot-dip plated layer after solidification partially changes accordingly, and the uniformity of the appearance pattern may decrease. The cause of decrease of the appearance pattern uniformity is considered to be a partial change in the size of the [Al phase], the size of the [ternary
10 eutectic structure of Al/MgZn₂/Zn], and abundance proportions of the [Al phase] and the [ternary eutectic structure of Al/MgZn₂/Zn].

[0017]

In addition, the inventors conducted extensive studies and found that, when image data of the surface of the hot-dip plated layer is acquired, and image analysis is
15 performed by a two-dimensional discrete Fourier transform on the image data, it is possible to objectively evaluate the satin-like appearance pattern uniformity.

[0018]

Specifically, it is found that, when a plurality of areas with a predetermined size are selected from the surface of the hot-dip plated layer, grayscale image data is acquired
20 for each area, a two-dimensional discrete Fourier transform is performed on these image data items, and the obtained amplitude spectrum images of spatial frequencies are analyzed, the analysis results of the amplitude spectrum images and the size of the satin-like pattern are correlated, and additionally, when the variation of the analysis results of the amplitude spectrum images is evaluated, it is possible to identify a hot-dip plated
25 steel sheet having excellent appearance pattern uniformity.

[0019]

Hereinafter, the hot-dip plated steel sheet of the present embodiment will be described.

[0020]

5 The hot-dip plated steel sheet of the present embodiment includes a steel sheet and a hot-dip plated layer formed on the surface of the steel sheet, and the hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities, and when five square measurement areas with sides of 5 mm are selected from the surface of the hot-dip plated
10 layer and an intensity ratio A of each measurement area is obtained by the following measurement method, a ratio (A/A_{ave}) of an intensity ratio A of each measurement area to an average value A_{ave} of intensity ratios A of the five measurement areas is in a range of 0.70 or more and less than 1.40 in the hot-dip plated steel sheet.

[0021]

15 The measurement method is a method in which each measurement area is extracted as 256 level grayscale image data with a size of 50 pixels×50 pixels, a two-dimensional discrete Fourier transform is performed on the 256 gradation image data to obtain amplitude spectrum images of spatial frequencies, in the obtained amplitude spectrum images, a sum S25 of intensities of spatial frequencies 1 to 25 and a sum S5 of
20 intensities of spatial frequencies 1 to 5 are calculated, and a ratio ($S5/S25$) of the intensity sum S5 to the intensity sum S25 is defined as an intensity ratio A.

[0022]

 The material of the steel sheet used as the base of the hot-dip plated layer is not particularly limited. As the material, general steel or the like can be used without
25 particular limitation, Al killed steel or some high alloy steels can also be applied, and the

form is not particularly limited. When a hot-dip plating method to be described below is applied to the steel sheet, the hot-dip plated layer according to the present embodiment is formed.

[0023]

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

The hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities. More

preferably, the hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities. In

10 addition, the average composition of the hot-dip plated layer may contain Si: 0.0001 to 2 mass%. In addition, the average composition of the hot-dip plated layer may contain a total of 0.0001 to 2 mass% of one or more of a group consisting of Ni, Ti, Zr, and Sr. In addition, the average composition of the hot-dip plated layer may contain a total of 0.0001 to 2 mass% of one or more of a group consisting of Fe, Sb, Pb, Sn, Ca, Co, Mn, P, 15 B, Bi, Cr, Sc, Y, REM, and Hf.

[0024]

The Al content in the average composition is in a range of 2 to 22 mass%. Al may be contained in order to secure corrosion resistance. If the Al content in the hot-dip plated layer is 2 mass% or more, an effect of improving corrosion resistance is further 20 improved. If the Al content exceeds 22 mass%, the corrosion resistance decreases although the cause is unknown. In consideration of corrosion resistance, the Al content is preferably 4 to 22 mass%, and more preferably 5 to 18 mass%. The Al content is still more preferably 6 to 16 mass%.

[0025]

25 The Mg content in the average composition is in a range of 0.1 to 10 mass%.

Mg can be contained in order to improve corrosion resistance. If the Mg content in the hot-dip plated layer is 0.1 mass% or more, an effect of improving corrosion resistance is further improved. If the Mg content exceeds 10 mass%, the occurrence of dross in the plating bath becomes significant, and there are locations in which the plating may not be formed normally due to adhesion of dross to the plating so that the corrosion resistance may decrease. Therefore, the Mg content is 10 mass% or less. In consideration of decrease of corrosion resistance due to the occurrence of dross, the Mg content is preferably 1.0 to 10 mass%, and more preferably 1.5 to 6.0 mass%. The Mg content is still more preferably in a range of 2.0 to 5.0 mass%.

10 [0026]

In addition, Si may or may not be contained because it may improve the adhesion of the hot-dip plated layer. Since an effect of improving adhesion is exhibited if the Si content is 0.0001 mass% or more, the Si content is preferably 0.0001 mass% or more. On the other hand, the Si content is set to 2 mass% or less because an effect of improving plating adhesion has already been saturated when the Si content exceeds 2 mass%. In consideration of plating adhesion, the Si content may be in a range of 0.0001 to 1 mass% or in a range of 0.01 to 0.8 mass%.

[0027]

In addition, the average composition of the hot-dip plated layer may contain a total of 0.0001 to 2 mass% of one or more of the group consisting of Ni, Ti, Zr, and Sr. In addition, the average composition of the hot-dip plated layer may contain a total of 0.0001 to 2 mass% of one or more of the group consisting of Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, and Hf. When these elements are contained, it is possible to further improve corrosion resistance. REM is one or more of rare earth elements having an atomic number of 57 to 71 in the periodic table.

[0028]

The remainder of the chemical composition of the hot-dip plated layer is made up of zinc and impurities. The impurities include those that are inevitably contained in base metals such as zinc and those that are contained when steel is melted in a plating bath.

[0029]

Here, the average composition of the hot-dip plated layer can be measured by the following method. First, a surface layer coating film is removed with a coating film remover (for example, Neo Rever SP-751 commercially available from Sansai Kako Co., Ltd.) that does not erode the plating, and the hot-dip plated layer is then dissolved with hydrochloric acid containing an inhibitor (for example, Hibiron commercially available from SUGIMURA Chemical Industrial Co., Ltd.), the obtained solution is subjected to inductively coupled plasma (ICP) emission spectroscopy analysis, and thus the average composition can be determined. In addition, when the surface layer coating film is not provided, an operation of removing the surface layer coating film can be omitted.

[0030]

Next, the structure of the hot-dip plated layer will be described. Specifically, each structure will be exemplified using a case in which the hot-dip plated layer has an average composition containing Al: 11 mass%, Mg: 3 mass%, Si: 0.2 mass%, with the remainder including Zn and impurities. The hot-dip plated layer containing Al, Mg and Zn contains the [Al phase] and the [ternary eutectic structure of Al/Zn/MgZn₂]. It has a form in which the [Al phase] is contained in the base of the [ternary eutectic structure of Al/Zn/MgZn₂]. In addition, the [MgZn₂ phase] and the [Zn phase] may be contained in the base of the [ternary eutectic structure of Al/Zn/MgZn₂]. In addition, when the hot-dip plated layer contains Si, the [Mg₂Si phase] may be contained in the base of the

[ternary eutectic structure of Al/Zn/MgZn₂].

[0031]

As shown in Fig. 1, in the SEM image, the [ternary eutectic structure of Al/Zn/MgZn₂] is a part expressed by a white area, a gray area, and a fine white and black mixed area. The [ternary eutectic structure of Al/Zn/MgZn₂] is a ternary eutectic structure of an Al phase, a Zn phase, and an intermetallic compound MgZn₂ phase, and the Al phase forming the [ternary eutectic structure of Al/Zn/MgZn₂] corresponds to, for example, an “Al” phase” (an Al solid solution in which Zn is solid-solutionized and containing a small amount of Mg) at a high temperature in the ternary Al-Zn-Mg equilibrium state diagram. The Al” phase at a high temperature generally separately appears as a fine Al phase and a fine Zn phase at room temperature. In addition, the Zn phase in the [ternary eutectic structure of Al/Zn/MgZn₂] is a Zn solid solution in which a small amount of Al is solid-solutionized and in some cases, a small amount of Mg is additionally solid-solutionized. The MgZn₂ phase in the [ternary eutectic structure of Al/Zn/MgZn₂] is an intermetallic compound phase present in the vicinity of Zn: about 84 mass% in the Zn-Mg binary equilibrium state diagram. It is thought that, in each phase shown in the state diagram, other additives elements are not solid-solutionized or are solid-solutionized but only in a very small amount, and the amount thereof cannot be clearly distinguished by general analysis. Therefore, the ternary eutectic structure composed of these three phases is referred to as [ternary eutectic structure of Al/Zn/MgZn₂] in this specification.

[0032]

As shown in Fig. 1, the [Al phase] is a part represented with a state color in which a white color and a black color are finely mixed, which appears like islands with clear boundaries in the base of the [ternary eutectic structure of Al/Zn/MgZn₂] in the

SEM image. The [Al phase] corresponds to, for example, an “Al” phase” (an Al solid solution in which Zn is solid-solutionized and containing a small amount of Mg) at a high temperature in the ternary Al-Zn-Mg equilibrium state diagram. In the Al” phase at a high temperature, the amount of Zn and the amount of Mg that are solid-solutionized differ depending on the concentrations of Al and Mg in the plating bath. The Al” phase at a high temperature generally separately appears as a fine Al phase and a fine Zn phase at room temperature, but the island-like shapes appearing at room temperature can be seen as a retention of the framework of the Al” phase at a high temperature. It is thought that, in this phase seen in the state diagram, other additive elements are not solid-solutionized or are solid-solutionized but only in a very small amount, and they cannot be clearly distinguished by general analysis. Therefore, the phase derived from the Al” phase at a high temperature and having a shape of retaining the framework of the Al” phase is referred to as an [Al phase] in this specification. The [Al phase] can be clearly distinguished from the Al phase forming the [ternary eutectic structure of Al/Zn/MgZn₂] in microscopic observation.

[0033]

As shown in Fig. 1, the [Zn phase] is a part represented with a white color, which appears like islands with clear boundaries in the base of the [ternary eutectic structure of Al/Zn/MgZn₂] in the SEM image. In the [Zn phase], actually, a small amount of Al and additionally, a small amount of Mg are solid-solutionized in some cases. An area having a circle-equivalent diameter of 2.5 μm or more is defined as the Zn phase. It is thought that, in this phase seen in the state diagram, other additive elements are not solid-solutionized or are solid-solutionized but only in a very small amount. This [Zn phase] can be clearly distinguished from the Zn phase forming the [ternary eutectic structure of Al/Zn/MgZn₂] in microscopic observation. The plating

layer of the present invention may contain the [Zn phase] depending on the plating composition and production conditions. However, because almost no effect on the improvement of corrosion resistance of a processed part was observed in the experiment, there is no particular problem even if the plating layer contains the [Zn phase].

5 [0034]

As shown in Fig. 1, the [MgZn₂ phase] is a part represented with gray, which appears like islands with clear boundaries in the base of the [ternary eutectic structure of Al/Zn/MgZn₂] in the SEM image. In the [MgZn₂ phase], actually, a small amount of Al is solid-solutionized in some cases. It is thought that, in this phase seen in the state
10 diagram, other additive elements are not solid-solutionized or are solid-solutionized but only in a very small amount. This [MgZn₂ phase] can be clearly distinguished from the MgZn₂ phase forming the [ternary eutectic structure of Al/Zn/MgZn₂] in microscopic observation. The plating layer of the present invention may not contain the [MgZn₂ phase] depending on the plating composition and production conditions, but the [MgZn₂
15 phase] is contained in the plating layer under most production conditions.

[0035]

As shown in Fig. 1, the [Mg₂Si phase] is a part represented with black, which appears like islands with clear boundaries in the solidified structure of the hot-dip plated layer when Si is contained in the SEM image. It is thought that, in the [Mg₂Si phase]
20 seen in the state diagram, Zn, Al, and other additive elements are not solid-solutionized or are solid-solutionized but only in very small amount. The [Mg₂Si phase] can be clearly distinguished in microscopic observation in the plating.

[0036]

Next, the appearance of the hot-dip plated layer will be described.

25 In the hot-dip plated layer according to the present embodiment, when five

square measurement areas with sides of 5 mm are selected from the surface of the hot-dip plated layer and an intensity ratio A of each measurement area is obtained by the following measurement method, it is necessary to set a ratio (A/A_{ave}) of an intensity ratio A of each measurement area to an average value A_{ave} of intensity ratios A of the five measurement areas to be within a range of 0.70 or more and less than 1.40.

[0037]

The five measurement areas may be arbitrarily selected, but the distance between the measurement areas is preferably, for example, 10 cm or less. If the distance between the measurement areas is more than 10 cm, it is difficult to appropriately determine the uniformity of the appearance pattern such as a satin pattern and there is a risk of inconsistency with the visual determination result of the uniformity of the appearance pattern. When the uniformity of the appearance pattern such as a satin pattern is visually determined, a range of 10 cm square is visually determined in many cases in consideration of the size of the pattern. Therefore, in the present embodiment, the distance between the measurement areas is 10 cm or less. More specifically, at any position on the surface of the plating layer, a square area with a side of 10 cm is selected, and at a total of 5 positions, four corners of the square and the intersection of two diagonal lines of the square, measurement square areas with sides of 5 mm may be selected.

20 [0038]

A sample including the selected measurement area and its surroundings is cut out from the hot-dip plated steel sheet, and image data of the measurement area is extracted using this sample.

[0039]

25 The image data of the measurement area is extracted by scanning the surface of

the hot-dip plated layer of the sample with a scanner connected to a computer. The measurement area is extracted as 256 level grayscale image data with a size of 50 pixels×50 pixels. The scanner to be used may be, for example, a flat bed type scanner. Generally, in the acquisition of the image data with a scanner, since image correction is performed for each acquisition, it is preferable to extract the measurement area by trimming after image data of the entire sample is acquired at one time. In addition, with a general scanner, image data with a large number of pixels of 50 pixels or more is acquired for 5 mm, it is better to re-size the image to 50 pixels×50 pixels using computer software.

10 [0040]

Generally, image data can be extracted by taking a picture, but in the case of taking a picture, because it is difficult to emit the uniform illumination light for taking the picture to the entire hot-dip plated layer that is a subject, and it may not be possible to accurately evaluate the appearance pattern, extraction with a scanner is preferable.

15 [0041]

In addition, the image data is 256 level grayscale image data. The image data includes a binarized image, a gradation image, a color image and the like, but the binarized image is represented by two light and dark values, and the amount of information is insufficient. In addition, in the color image, since pixels have color information, the amount of information is excessive. Since the surface appearance of the hot-dip plated layer of the present embodiment has low saturation, grayscale gradation image data is sufficient as the amount of information. Therefore, in the present embodiment, a 256 level grayscale image having an appropriate amount of information and a gradation of 0 to 255 steps that is easy to handle by a computer is preferable.

20

25

[0042]

In addition, when a measurement square area with a side of 5 mm is extracted as gradation image data with a size of 50 pixels×50 pixels, the gradation image data includes 2,500 pixels. Each pixel will have brightness data in a square area with a side of 0.1 mm, which reflects the appearance pattern such as a satin pattern. Theoretically, even if the size of the measurement area and the number of pixels increase, the same tendency of measurement results can be obtained, but in order to reduce the calculation load, the measurement area of 5 mm and 50 pixels, which is the minimum size at which there are no practical issues, is set.

10 [0043]

Next, a two-dimensional discrete Fourier transform is performed on the obtained gradation image data of the measurement area to obtain amplitude spectrum images of spatial frequencies. The two-dimensional discrete Fourier transform may be performed by a computer having a program installed in advance.

15 [0044]

The two-dimensional discrete Fourier transform is performed using the following (Formula 1). $f(x, y)$ is a pixel value at a position of (x, y) , and $F(u, v)$ is a complex number indicating a sine wave at a position of a spatial frequency (u, v) . In addition, u is a frequency of the x component, and v is a frequency of the y component.

20 In the present embodiment, since gradation image data with a size of 50 pixels×50 pixels is used, M and N are 50. When an absolute value of the complex number indicating a sine wave is obtained, an amplitude spectrum image is obtained. For the obtained amplitude spectrum image, in order to improve ease of handling of data, an operation of switching a first quadrant with a third quadrant and a second quadrant with a fourth quadrant is performed.

25

[0045]

[Math. 1]

$$F(u, v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) e^{-2\pi i \left(\frac{ux}{M} + \frac{vy}{N} \right)} \quad \dots$$

Formula 1

[0046]

5 For example, when the pattern on the plating surface is a rough pear skin like pattern, if a two-dimensional discrete Fourier transform is performed to a sample, many sine waves with a relatively small frequency component are included. On the other hand, when the pattern on the plating surface is a fine pear skin like pattern, if a two-dimensional discrete Fourier transform is performed to a sample, many sine waves with a
10 relatively large frequency component are included. The amplitude spectrum images of spatial frequencies after the two-dimensional discrete Fourier transform is performed reflect the results of such a two-dimensional discrete Fourier transform.

[0047]

Fig. 2 shows an example of gradation image data and an example of an
15 amplitude spectrum image of a spatial frequency obtained by performing a two-dimensional discrete Fourier transform on the gradation image data. The amplitude spectrum image shows an amplitude of a sine wave with a lower frequency component as it approaches the center of the image, and shows an amplitude of a sine wave with a higher frequency component as it is away from the center concentrically. In the
20 amplitude spectrum image shown in Fig. 2, the magnitude (intensity) of the amplitude of the sine wave is represented by shading, with darker colors indicating higher intensity and lighter colors indicating lower intensity. That is, the spatial spectrum image shown in Fig. 2 shows that the intensity of the sine wave with low frequency is higher than those

with low frequency.

[0048]

Then, as shown in Fig. 2, in the amplitude spectrum image of spatial frequencies for each gradation image data item, a sum S25 of intensities of spatial frequencies 1 to 25 and a sum S5 of intensities of spatial frequencies 1 to 5 can be calculated. Here, the sum S25 of intensities of spatial frequencies 1 to 25 or more is a sum of intensities in the area surrounded by the outer circle in Fig. 2, and the sum S5 of intensities of spatial frequencies 1 to 5 is a sum of intensities in the area surrounded by the inner circle in Fig. 2. In both intensity sum calculations, the intensity of the spatial frequency 0, located in the center of the amplitude spectrum image, is excluded. From the intensity sum S25 and the intensity sum S5, an intensity ratio A which is a ratio ($S5/S25$) of the intensity sum S5 to the intensity sum S25 can be obtained.

[0049]

In the amplitude spectrum image of spatial frequencies for each gradation image data item, when the intensity ratio A is relatively large, the sum S5 of intensities of spatial frequencies 1 to 5 is large, and the amount of low spatial frequency components is large. Accordingly, the gradation image data having a relatively large intensity ratio A has a relatively rough pear skin-like appearance. On the other hand, in the spatial frequency spectrum image for each gradation image data item, when the intensity ratio A is relatively small, the sum S5 of intensities of spatial frequencies 1 to 5 is small and the amount of low spatial frequency components is small. Accordingly, the gradation image data having a relatively small intensity ratio A has a relatively fine pear skin-like appearance. As described above, the intensity ratio A is a parameter that can objectively evaluate the fineness of the pattern.

[0050]

Fig. 3 shows an example of various gradation image data items and amplitude spectrum images of spatial frequencies obtained from the gradation image data items.

In Fig. 3, the upper images are gradation image data items, the lower images are

amplitude spectrum images, and Fig. 3 shows five sets of image data items. The pear

5 skin-like pattern becomes rougher toward the right side from the left side in Fig. 3. It

can be understood that, as the pear skin-like pattern becomes rougher, the intensity at the center of the spatial frequency spectrum image is higher, and the intensity ratio A is

larger.

[0051]

10 In the same manner as described above, a two-dimensional discrete Fourier transform is performed on gradation image data items extracted from arbitrary five areas on the hot-dip plated layer to obtain an intensity ratio A . In addition, an average value A_{ave} of the obtained five intensity ratios A is obtained.

[0052]

15 In the hot-dip plated layer of the present embodiment, it is necessary for the ratio (A/A_{ave}) of the intensity ratio A of each of the five measurement areas to the average value A_{ave} to be in a range of 0.70 or more and less than 1.40. If the ratio (A/A_{ave}) of the intensity ratio A in one area among the five measurement areas is less than 0.70 or 1.40 or more, the uniformity of the appearance pattern decreases. The ratio (A/A_{ave}) may be

20 0.80 or more or 0.85 or more. In addition, the ratio (A/A_{ave}) may be 1.30 or less or 1.20 or less. When the ratio (A/A_{ave}) in the five measurement areas is closer to 1.00, the appearance pattern uniformity becomes better.

[0053]

Next, a method of producing a hot-dip plated steel sheet of the present

25 embodiment will be described. Fig. 4 shows a hot-dip plating facility suitable for

producing the hot-dip plated steel sheet of the present embodiment. The hot-dip plating facility shown in Fig. 4 includes a hot-dip plating bath 2, a sink roller 3 disposed in the hot-dip plating bath 2, a wiping nozzle 4 disposed above the hot-dip plating bath 2, an electromagnetic damping device 5 disposed above the wiping nozzle 4, a cooling device 6 disposed above the electromagnetic damping device 5, and a top roller 7 disposed above the cooling device 6.

[0054]

The hot-dip plating bath 2 preferably contains Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities. In addition, the hot-dip plating bath may contain Si: 0.0001 to 2 mass%. In addition, the hot-dip plating bath may contain a total of 0.0001 to 2 mass% of any one or more of Ni, Ti, Zr, and Sr. In addition, the hot-dip plating bath may contain a total of 0.0001 to 2 mass% of any one or more of Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y, REM, and Hf. Here, the average composition of the hot-dip plated layer of the present embodiment is almost the same as the composition of the hot-dip plating bath 2. The temperature of the hot-dip plating bath 2 varies depending on the composition, and is preferably, for example, in a range of 400 to 500°C. This is because, if the temperature of the hot-dip plating bath 2 is within this range, a desired hot-dip plated layer can be formed.

[0055]

The electromagnetic damping device 5 prevents the steel sheet from vibrating and a generally known device can be used. The electromagnetic damping device 5 includes, for example, a pair of electromagnet that are symmetrically disposed on both sides of a traveling steel sheet 1 at a predetermined distance (for example, 20 to 30 mm), and more desirably, two or more electromagnets on one side in the plate width direction and a non-contact type steel band position detector, and has a function of preventing

vibration of the steel sheet so that the waviness in the plate width direction is removed by controlling the attractive force of each electromagnet by a control device based on the detection signal of the steel band position detector. It is desirable that the electromagnetic damping device 5 be installed within a range of 1 m from the cooling start position (when a refrigerant is injected toward the steel sheet, the center position at which the refrigerant is applied to the steel sheet) of the cooling device 6 in the direction opposite to the traveling direction of the steel sheet 1. That is, the device may be installed near the entrance of the cooling device 6. It is desirable that the amplitude of the steel sheet (a maximum amplitude of the steel sheet in the cooling device) out of the electromagnetic damping device be within 40 mm. In addition, it is desirable to operate the electromagnetic damping device in a range of 0.03 to 0.06 T.

[0056]

Hereinafter, a method of producing a hot-dip plated steel sheet using the production facility in Fig. 4 will be described. First, a hot-rolled steel sheet is produced, and as necessary, the hot-rolled sheet is annealed. After pickling, cold rolling is performed to obtain a cold-rolled sheet. The cold-rolled sheet is degreased and washed, and then annealed (the cold-rolled sheet is annealed).

[0057]

Next, as shown in Fig. 4, after the annealed steel sheet 1 is immersed in the hot dip galvanizing bath 2, the sink roller 3 changes the traveling direction and pulls the sheet up in the vertical direction. A high-pressure gas such as air and nitrogen is blown to the surface of the pulled steel sheet 1 from the wiping nozzle 4 disposed above the hot dip galvanizing bath 2, and thus an excessive adhesion amount of the hot-dip plating adhered to the surface of the steel sheet 1 is removed.

[0058]

The adhesion amount of the hot-dip plated layer is preferably adjusted so that a total adhesion amount on both sides of the steel sheet is in a range of 30 to 600 g/m².

When the adhesion amount is less than 30 g/m², this is not preferable because corrosion resistance of the hot-dip plated steel sheet decreases. When the adhesion amount

5 exceeds 600 g/m², this is not preferable because the molten metal adhered to the steel sheet drips and the surface of the hot-dip plated layer cannot be smoothed.

[0059]

Next, as shown in Fig. 4, the electromagnetic damping device 5 minimizes vibration of the steel sheet 1 and introduces the steel sheet 1 into the cooling device 6.

10 The steel sheet 1 of which vibration is minimized by the electromagnetic damping device 5 is introduced into the cooling device 6. The cooling device 6 has a built-in injection nozzle through which a refrigerant is injected toward the steel sheet, and a refrigerant such as a non-oxidizing gas or a non-oxidizing gas containing mist is injected toward the steel sheet 1 through which the injection nozzle. Since the refrigerant is injected while

15 the vibration of the steel sheet 1 is minimized, the distance between the injection nozzle and the steel sheet 1 becomes constant, and accordingly, a refrigerant with a substantially uniform injection speed and injection amount can be applied to the entire hot-dip plated layer, and the cooling speed on the hot-dip plated layer becomes substantially uniform over the entire surface of the hot-dip plated layer. Therefore, the metal structure and

20 alloy composition of the hot-dip plated layer after solidification become substantially uniform, and the appearance pattern uniformity of the hot-dip plated layer is significantly improved. Here, in the conventional facility, for example, an electromagnetic damping device may be disposed near the wiping nozzle 4 in order to minimize a variation in the adhesion amount of the plating, but the electromagnetic damping device provided near

25 the wiping nozzle 4 is away from the cooling device 6, and thus an effect of minimizing

vibration of the sheet during cooling cannot be obtained.

[0060]

According to the hot-dip plated steel sheet of the present embodiment, since a ratio (A/A_{ave}) of an intensity ratio A of each measurement area to an average value A_{ave} of intensity ratios A of the five measurement areas selected from the surface of the hot-dip plated layer is in a range of 0.70 or more and less than 1.40, the uniformity of the appearance pattern becomes excellent. In addition, in the hot-dip plated steel sheet of the present embodiment, since the hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities, it has excellent corrosion resistance.

[Example 1]

[0061]

Next, examples of the present invention will be described. A steel sheet after cold rolling was degreased and washed with water. Then, the steel sheet was subjected to cold-rolled sheet annealing. The steel sheet after annealing the cold-rolled sheet was introduced into the hot-dip plating facility shown in Fig. 4, immersed in the hot-dip plating bath and then pulled up. Then, the adhesion amount was adjusted by gas wiping, and cooling was additionally performed. Cooling was performed by blowing a non-oxidizing gas in the cooling device while vibration of the steel sheet was minimized by the electromagnetic damping device. Here, as shown in Table 1A and Table 1B, the electromagnetic damping device changed its position from the cooling start position (the center position at which a non-oxidizing gas was applied to the steel sheet) in the direction opposite to the traveling direction of the steel sheet. In Table 1A and Table 1B, directly below the cooling device in the column of the damping device position means that “the damping device is within a range of 1 m from the cooling start position

in the direction opposite to the traveling direction of the steel sheet 1.” In addition, Table 1A and Table 1B show the maximum amplitude of the steel sheet in the cooling device. Accordingly, Nos. 1 to 52 of hot-dip plated steel sheets shown in Table 1A and Table 1B were produced.

5 [0062]

In addition, Nos. 53 and 54 of hot-dip plated steel sheets were produced in the same manner as in the Nos. 1 to 52 of hot-dip plated steel sheets except that vibration of the steel sheet was not minimized by the electromagnetic damping device.

[0063]

10 For the obtained hot-dip plated steel sheet, five square areas with sides of 5 mm on the surface of the hot-dip plated layer were selected as measurement areas, and each measurement area was extracted as gradation image data with a size of 50 pixels×50 pixels. The measurement area was selected as follows. At any position on the surface of the plating layer, a square area with a side of 10 cm was selected, and at a total of 5
15 positions, four corners of the square and the intersection of two diagonal lines of the square, measurement square areas with sides of 5 mm were selected. The image data of the measurement area was extracted by scanning the surface of the hot-dip plated layer of the sample with a flat bed type scanner connected to a computer. The image data was 256 level grayscale image data.

20 [0064]

Next, for each gradation image data item, a two-dimensional discrete Fourier transform was performed on the gradation image data to obtain amplitude spectrum images of spatial frequencies. In the amplitude spectrum image of spatial frequencies for each gradation image data item, a sum S25 of intensities of spatial frequencies 1 to 25
25 and a sum S5 of intensities of spatial frequencies 1 to 5 were calculated, and a ratio

(S5/S25) of the intensity sum S5 to the intensity sum S25 was obtained as an intensity ratio A . In addition, an average value A_{ave} of the five obtained intensity ratios A was obtained. Then, a ratio (A/A_{ave}) of the intensity ratio A of each of the five measurement areas to the average value A_{ave} was obtained. The results are shown in Tables 2A and 2B. In Tables 2A and 2B, “upper left corner,” “upper right corner,” “lower left corner,” and “lower right corner” are a ratio (A/A_{ave}) at the corner of a square with a side of 10 cm, and “center” is a ratio (A/A_{ave}) at the intersection of two diagonal lines of the square. Tables 2A and 2B show the results.

[0065]

When the ratios (A/A_{ave}) in the five measurement areas were all within a range of 0.70 or more and less than 1.40, it was evaluated as F indicating good appearance pattern uniformity, and when even one ratio (A/A_{ave}) in the five measurement areas did not satisfy 0.70 or more and less than 1.40, it was evaluated as P indicating insufficient appearance pattern uniformity. F was satisfactory, and P was unsatisfactory. Tables 2A and 2B show the results.

[0066]

In addition, the appearance pattern uniformity was visually evaluated. The plating appearance was visually evaluated. When pattern spots were not visible from 1 m ahead, it was evaluated as F indicating good appearance pattern uniformity, and when pattern spots were visible, it was evaluated as P indicating insufficient appearance pattern uniformity. F was satisfactory, and P was unsatisfactory. Tables 2A and 2B show the results.

[0067]

The corrosion resistance of the hot-dip plated steel sheet was evaluated by a corrosion weight loss after the CCT test. The plating steel sheet was cut to 150×70 mm,

and the corrosion weight loss was examined after 30 CCT cycles using CCT according to JASO-M609. A corrosion weight loss of less than 30 g/m² was evaluated as F, a corrosion weight loss of 30 g/m² or more and less than 50 g/m² was evaluated as G, a corrosion weight loss of 50 g/m² or more and less than 60 g/m² was evaluated as P, a corrosion weight loss of 60 g/m² or more was evaluated as X. F, G and P were satisfactory, and X was unsatisfactory. Tables 2A and 2B show the results.

[0068]

As shown in Table 1A, Table 1B, Table 2A and Table 2B, No. 1 to No. 46 of hot-dip plated steel sheets of the examples of the present invention had both excellent appearance pattern uniformity and corrosion resistance.

[0069]

On the other hand, as shown in Table 1A, Table 1B, Table 2A and Table 2B, No. 47 to No. 54 of hot-dip plated steel sheets of comparative examples had poor appearance pattern uniformity or poor corrosion resistance.

[0070]

In addition, regarding the evaluation of the appearance pattern uniformity, a sufficient correlation was observed between evaluation using the intensity ratio A according to the present invention and visual evaluation.

[0071]

[Table 1A]

No.	Production method			Hot-dip plated layer				
	Production method	Damping device position	Maximum amplitude of steel sheet in cooling device (mm)	Average composition (mass%) remainder: Zn and impurities				Adhesion amount of plating (total on both sides) (g/m ²)
				Al	Mg	Si	Other	
1	Minimize vibration of steel sheet	Directly below cooling device	20	11	3.0	0.2	-	270
2	Minimize vibration of steel sheet	Directly below cooling device	20	2	2.0	-	-	290
3	Minimize vibration of steel sheet	Directly below cooling device	30	3	2.0	-	-	280
4	Minimize vibration of steel sheet	Directly below cooling device	30	4	3.0	-	-	300
5	Minimize vibration of steel sheet	Directly below cooling device	20	5	3.0	-	-	280
6	Minimize vibration of steel sheet	Directly below cooling device	30	6	3.0	-	-	280
7	Minimize vibration of steel sheet	Directly below cooling device	30	16	3.0	0.4	-	270
8	Minimize vibration of steel sheet	Directly below cooling device	20	18	3.0	0.4	-	290
9	Minimize vibration of steel sheet	Directly below cooling device	20	22	3.0	0.2	-	400
10	Minimize vibration of steel sheet	Directly below cooling device	20	2	0.1	-	-	290
11	Minimize vibration of steel sheet	Directly below cooling device	20	6	0.8	-	-	270
12	Minimize vibration of steel sheet	Directly below cooling device	30	11	1.0	0.2	-	200
13	Minimize vibration of steel sheet	Directly below cooling device	20	11	1.5	0.2	-	350
14	Minimize vibration of steel sheet	Directly below cooling device	30	11	2.0	0.2	-	290

	of steel sheet	cooling device								
15	Minimize vibration of steel sheet	Directly below cooling device	10	11	5.0	0.2	-	-	-	280
16	Minimize vibration of steel sheet	Directly below cooling device	20	11	6.0	0.2	-	-	-	290
17	Minimize vibration of steel sheet	Directly below cooling device	10	11	10	0.2	-	-	-	300
18	Minimize vibration of steel sheet	Directly below cooling device	30	11	3.0	0.0001	-	-	-	280
19	Minimize vibration of steel sheet	Directly below cooling device	30	11	3.0	0.8	-	-	-	290
20	Minimize vibration of steel sheet	Directly below cooling device	20	18	3.0	1	-	-	-	270
21	Minimize vibration of steel sheet	Directly below cooling device	30	22	3.0	2	-	-	-	350
22	Minimize vibration of steel sheet	Directly below cooling device	10	11	3.0	0.2	Ni	0.1	-	270
23	Minimize vibration of steel sheet	Directly below cooling device	20	11	3.0	0.2	Ti	0.01	-	180
24	Minimize vibration of steel sheet	Directly below cooling device	30	11	3.0	0.2	Zr	0.0001	-	280
25	Minimize vibration of steel sheet	Directly below cooling device	20	11	3.0	0.2	Sr	0.01	-	270
26	Minimize vibration of steel sheet	Directly below cooling device	30	11	3.0	0.2	Fe	0.01	-	200
27	Minimize vibration of steel sheet	Directly below cooling device	30	11	3.0	0.2	Sb	0.01	-	80

[0072]

[Table 1B]

No.	Production method		Maximum amplitude of steel sheet in cooling device (mm)	Hot-dip plated layer				
	Production method	Damping device position		Average composition (mass%) remainder:				
				Zn and impurities				
				Al	Mg	Si	Other	
			Adhesion amount of plating (total on both sides) (g/m ²)					

28	Minimize vibration of steel sheet	Directly below cooling device	40		11	3.0	0.2	Pb	0.01	30
29	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	Sn	0.01	600
30	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	Ca	0.01	300
31	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	Co	0.01	400
32	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	Mn	0.01	300
33	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	P	0.01	200
34	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	B	0.0001	300
35	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	Bi	0.01	300
36	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	Cr	0.01	400
37	Minimize vibration of steel sheet	Directly below cooling device	10		11	3.0	0.2	Sc	0.01	300
38	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	Y	0.01	100
39	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	REM	0.01	300
40	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	Hf	0.01	50
41	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	-	-	280
42	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	-	-	270
43	Minimize vibration of steel sheet	Directly below cooling device	30		11	3.0	0.2	-	-	290
44	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	-	-	280
45	Minimize vibration of steel sheet	Directly below cooling device	20		11	3.0	0.2	-	-	280

46	Minimize vibration of steel sheet	Directly below cooling device	20	11	3.0	0.2	-	-	270
47	Minimize vibration of steel sheet	Directly below cooling device	30	<u>1</u>	2.0	-	-	-	280
48	Minimize vibration of steel sheet	Directly below cooling device	20	<u>23</u>	3.0	0.4	-	-	290
49	Minimize vibration of steel sheet	Directly below cooling device	20	5	=	-	-	-	270
50	Minimize vibration of steel sheet	Directly below cooling device	30	11	<u>11</u>	0.2	-	-	300
51	Minimize vibration of steel sheet	Directly above wiping	50	11	3.0	0.2	-	-	300
52	Weakly minimize vibration of steel sheet	Directly below cooling device	45	11	3.0	0.2	-	-	290
53	Without minimizing vibration of steel sheet	-	55	11	3.0	0.2	-	-	290
54	Without minimizing vibration of steel sheet	-	50	11	3.0	0.2	-	-	310

Underlined parts indicate values outside the scope of the present invention.

[0073]

[Table 2A]

No.	Hot-dip plated layer						Evaluation			Note
	Average value A_{ave}	Ratio (A/A_{ave})				Lower right corner	Appearance pattern uniformity		Corrosion resistance	
		Upper left corner	Upper right corner	Center	Lower left corner		Evaluation according A/A_{ave}	Visual evaluation		
1	0.12	1.05	1.04	0.89	1.06	0.96	F	F	F	Example of invention
2	0.10	0.89	0.88	1.20	0.98	0.95	F	F	P	
3	0.09	1.08	1.05	1.07	0.91	0.89	F	F	P	
4	0.13	0.98	1.01	0.97	1.04	1.00	F	F	G	
5	0.11	1.06	1.07	0.87	0.89	1.11	F	F	F	
6	0.10	0.95	1.07	0.91	0.98	1.09	F	F	F	

7	0.15	0.93	0.89	0.93	1.09	1.16	F	F	F
8	0.17	1.09	0.95	0.88	0.89	1.19	F	F	F
9	0.19	1.02	1.08	0.94	1.00	0.96	F	F	G
10	0.12	0.87	1.20	0.98	0.75	1.20	F	F	P
11	0.10	1.01	0.91	1.03	0.93	1.12	F	F	P
12	0.11	0.98	0.93	0.96	0.95	1.18	F	F	G
13	0.12	0.96	0.89	1.09	1.04	1.02	F	F	F
14	0.11	0.93	0.87	1.04	0.98	1.18	F	F	F
15	0.13	1.01	1.08	0.97	0.96	0.98	F	F	F
16	0.14	1.00	1.05	0.91	0.87	1.17	F	F	F
17	0.18	1.04	1.01	1.07	0.92	0.96	F	F	G
18	0.11	1.05	0.93	0.87	1.04	1.11	F	F	F
19	0.12	0.91	1.02	0.89	1.04	1.14	F	F	F
20	0.20	0.99	1.07	1.05	0.86	1.03	F	F	F
21	0.19	1.08	0.92	0.89	1.01	1.10	F	F	F
22	0.09	1.06	1.08	0.90	0.93	1.03	F	F	F
23	0.10	1.05	0.99	0.93	0.86	1.17	F	F	F
24	0.10	0.88	0.92	1.06	0.95	1.19	F	F	F
25	0.10	0.99	1.08	1.05	0.87	1.01	F	F	F
26	0.14	0.94	1.09	1.06	0.86	1.05	F	F	F
27	0.13	1.00	0.94	0.95	1.05	1.06	F	F	F

[0074]

[Table 2B]

No.	Hot-dip plated layer						Evaluation		Note
	Average value A_{ave}	Ratio (A/A_{ave})				Appearance pattern uniformity	Corrosion resistance		
		Upper left corner	Upper right corner	Center	Lower left corner			Lower right corner	
28	0.12	1.02	0.93	1.05	0.98	1.02	F	F	Example of invention
29	0.13	0.89	0.97	1.06	1.08	1.00	F	F	
30	0.16	0.93	1.04	1.08	1.05	0.90	F	F	
31	0.15	1.05	1.06	0.93	0.93	1.03	F	F	
32	0.18	1.08	1.00	0.94	1.03	0.95	F	F	

33	0.12	0.96	1.01	0.99	0.87	1.17	F	F	
34	0.13	1.07	1.09	1.06	0.91	0.87	F	F	
35	0.11	1.03	0.86	1.07	1.04	1.00	F	F	
36	0.11	1.07	0.97	1.01	0.97	0.98	F	F	
37	0.13	1.04	0.98	0.99	0.94	1.05	F	F	
38	0.13	1.06	1.00	0.99	1.07	0.88	F	F	
39	0.12	1.01	1.09	1.05	0.97	0.88	F	F	
40	0.13	1.06	1.07	0.96	0.86	1.05	F	F	
41	0.12	1.07	1.08	1.10	1.05	0.70	F	F	
42	0.18	0.99	1.06	1.01	0.80	1.14	F	F	
43	0.14	0.96	0.85	1.06	0.96	1.17	F	F	
44	0.16	1.01	1.20	0.89	1.00	0.90	F	F	
45	0.17	0.95	0.92	0.90	0.93	1.30	F	F	
46	0.18	1.39	0.90	0.88	0.96	0.87	F	F	
47	0.10	1.20	0.80	1.10	0.95	0.95	F	F	
48	0.17	0.90	1.05	1.05	1.02	0.98	F	F	Comparative Example
49	0.10	1.01	0.91	1.03	0.93	1.12	F	F	
50	0.18	1.06	0.88	1.04	0.96	1.06	F	F	
51	0.14	1.10	<u>0.67</u>	0.95	1.20	1.08	P	P	
52	0.13	1.05	0.85	<u>1.43</u>	0.86	0.81	P	P	
53	0.14	0.91	0.92	0.87	<u>1.44</u>	0.86	P	P	
54	0.15	1.10	<u>0.68</u>	1.13	0.98	1.11	P	P	

Underlined parts indicate values outside the scope of the present invention.

[CLAIMS]

What is claimed is:

1. A hot-dip plated steel sheet comprising a steel sheet and a hot-dip plated layer formed on a surface of the steel sheet,

5 wherein the hot-dip plated layer has an average composition containing Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with a remainder comprising Zn and impurities, wherein, when five square measurement areas with sides of 5 mm are selected from a surface of the hot-dip plated layer and intensity ratios A of each measurement area are obtained by a following measurement method, a ratio (A/A_{ave}) of an intensity ratio A
10 of each measurement area to an average value A_{ave} of the intensity ratios A of the five measurement areas is in a range of 0.70 or more and less than 1.40, and

 wherein the measurement method is a method in which each measurement area is extracted as 256 level grayscale image data with a size of 50 pixels×50 pixels, a two-dimensional discrete Fourier transform is performed on the 256 gradation image data to
15 obtain amplitude spectrum images of spatial frequencies, and in the obtained amplitude spectrum images, a sum S25 of intensities of spatial frequencies 1 to 25 and a sum S5 of intensities of spatial frequencies 1 to 5 are calculated, and a ratio ($S5/S25$) of the intensity sum S5 to the intensity sum S25 is defined as an intensity ratio A.

20 2. The hot-dip plated steel sheet according to claim 1,

 wherein the hot-dip plated layer has an average composition containing Al: 4 to 22 mass% and Mg: 1 to 10 mass%.

3. The hot-dip plated steel sheet according to claim 1 or 2,

25 wherein the hot-dip plated layer further contains Si: 0.0001 to 2 mass% in the

average composition.

4. The hot-dip plated steel sheet according to any one of claims 1 to 3,

wherein the hot-dip plated layer further contains a total of 0.0001 to 2 mass% of

5 one or more of a group consisting of Ni, Ti, Zr, and Sr in the average composition.

5. The hot-dip plated steel sheet according to any one of claims 1 to 4,

wherein the hot-dip plated layer further contains a total of 0.0001 to 2 mass% of

one or more of a group consisting of Fe, Sb, Pb, Sn, Ca, Co, Mn, P, B, Bi, Cr, Sc, Y,

10 REM, and Hf in the average composition.

6. The hot-dip plated steel sheet according to any one of claims 1 to 5,

wherein an adhesion amount of the hot-dip plated layer is a total of 30 to 600 g/m²

on both sides of the steel sheet.