

[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 in which defects are inconspicuous. Priority is claimed on Japanese Patent Application No. 2020-061206, 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. Galvanized 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 hot-dip 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 describes 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 uniformity is improved. In recent years, various techniques for improving the appearance of the hot-dip Zn-Al-Mg-based hot-dip plated steel sheet have been proposed (Patent Documents 2 to 4).

[0007]

5 However, the Zn-Al-Mg-based hot-dip plated steel sheet with an improved appearance has a problem that defects become more conspicuous when surface defects occur during handling of the steel sheet. In particular, if the satin-like appearance of the Zn-Al-Mg-based hot-dip plated steel sheet is used as a part of the product design, there is a problem that defects are conspicuous.

10 [Citation List]

[Patent Document]

[0008]

[Patent Document 1]

PCT International Publication No. WO 2000/071773

15 [Patent Document 2]

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

[Patent Document 3]

Japanese Patent No. 4542434

[Patent Document 4]

20 Japanese Patent No. 5482914

[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
25 object of the present invention is to provide a hot-dip plated steel sheet in which defects

are inconspicuous and which has excellent corrosion resistance.

[Means for Solving the Problem]

[0010]

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

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

10 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 for each measurement
area are obtained by a following measurement method, at least one 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 0.50 to 0.65 or 1.45 to 2.00, and

15 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
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
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 the intensity ratio A.

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

25 [3] The hot-dip plated steel sheet according to [1] or [2], wherein the average

composition of the hot-dip plated layer further contains Si: 0.0001 to 2 mass%.

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

5 [5] The hot-dip plated steel sheet according to any one of [1] to [4], wherein the average composition of the hot-dip plated layer further contains 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.

[6] The hot-dip plated steel sheet according to any one of [1] to [5], wherein an
10 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
15 sheet in which defects are inconspicuous and which has 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
20 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
25 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.

5 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
10 mass% and Mg: 0.1 to 10 mass% is mainly composed of 4 types of phases and structures of [Al phase], [Zn phase], [MgZn₂ 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.

15 [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
20 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 uniformity is improved.

25 [0015]

However, if physical defects (scratch marks, friction marks, etc.) occur on the surface of the hot-dip plated layer when the appearance uniformity is improved, a new problem in which defects are conspicuous occurs. In addition, the appearance of the hot-dip plated layer is improved as the satin pattern becomes uniform, but the improvement of the plating appearance is not limited to this, and for example, the disordered appearance of patterns of various sizes may also improve the overall appearance, as in a zinc plated steel sheet having a spangle pattern.

[0016]

Therefore, 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 performed by a two-dimensional discrete Fourier transform on the brightness of pixels constituting the image data, it is possible to objectively evaluate the inconspicuousness of defects in the hot-dip plated steel sheet as the disorder of patterns, and found that it is possible to identify a hot-dip plated steel sheet in which defects are less conspicuous by this evaluation method.

[0017]

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 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 the disorder of satin-like patterns, that is, inconspicuousness of defects.

[0018]

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

[0019]

The hot-dip plated steel sheet of the present embodiment includes a steel sheet
5 and a hot-dip plated layer formed on the surface of the steel sheet, and the average
composition of the hot-dip plated layer contains 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
layer and an intensity ratio A of each measurement area is obtained by the following
10 measurement method, at least one 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 0.50 to 0.65 or 1.45 to 2.00 in the hot-dip plated steel sheet.

[0020]

In the measurement method, each measurement area is extracted as 256 level
15 grayscale image data with a size of 50 pixels×50 pixels, and a two-dimensional discrete
Fourier transform is performed on the 256 gradation image data to amplitude spectrum
images of spatial frequencies. In the 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
20 S25 is defined as an intensity ratio A in the method.

[0021]

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
particular limitation, Al killed steel or some high alloy steels can also be applied, and the
25 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.

[0022]

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

5 The average composition of the hot-dip plated layer contains Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities. More preferably, the average composition of the hot-dip plated layer contains Al: 2 to 22 mass%, and Mg: 0.1 to 10 mass%, with the remainder including Zn and impurities. In addition, the average composition of the hot-dip plated layer may contain Si: 0.0001 to 2 mass%. In addition,
10 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.

15 [0023]

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 improved. If the Al content exceeds 22 mass%, the corrosion resistance decrease
20 although the cause is unknown. If the Al content exceeds 22 mass%, an effect of improving corrosion resistance is saturated. 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%.

[0024]

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 a 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 [0025]

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%.

[0026]

The average composition of the hot-dip plated layer may contain a total of 0.0001 to 2 mass% of one or more 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 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.

[0027]

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.

[0028]

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.

[0029]

Next, the structure of the hot-dip plated layer will be described. Specifically, each structure will be exemplified using a case in which the average composition of the hot-dip plated layer contains Al: 11 mass%, Mg: 3 mass%, Si: 0.2 mass%, with the remainder including Zn and impurities (Fig. 1). 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].

[0030]

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 a small amount of Mg is additionally solid-solutionized in some cases. 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.

[0031]

As shown in Fig. 1, the [Al phase] is a part represented with a state 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.

[0032]

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. An area having a circle-equivalent diameter of 2.5 μm or more is defined as the Zn phase. In the [Zn phase], actually, a small amount of Al and additionally, a small amount of Mg are solid-solutionized in some cases. 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 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 [0033]

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. It is thought that, in this phase seen in the state diagram, other
10 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 production conditions, but the [MgZn₂ phase] is contained in the plating layer under
15 most production conditions.

[0034]

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.

[0035]

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 an

intensity ratio A for each measurement area is obtained by the following measurement method for five measurement areas selected from the surface of the hot-dip plated layer, it is necessary for at least one 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

5 0.50 to 0.65 or 1.45 to 2.00.

[0036]

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

10 appropriately determine the disorder of appearance patterns such as a satin pattern, and there is a risk of inconsistency with the visual determination result of the inconspicuousness of defects. When the inconspicuousness of defects 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

15 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 [0037]

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.

[0038]

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 [0039]

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 disorder of patterns, extraction with a scanner is preferable.

15 [0040]

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.

25

[0041]

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, a measurement area of 5 mm and 50 pixels, which is a minimum size at which there are no practical issues, is set.

10 [0042]

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 [0043]

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 the 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

[0044]

[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

[0045]

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

[0046]

Fig. 2 shows an example of gradation image data and an example of an amplitude spectrum image of a spatial frequency obtained by performing a two-
15 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 spatial spectrum image shown in Fig. 2, the magnitude (intensity) of the amplitude of the sine
20 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 having a low frequency component is high

among sine waves of all frequencies.

[0047]

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 any of intensity sum calculations, the intensity of the spatial frequency 0 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.

[0048]

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 satin-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 satin-like appearance. As described above, the intensity ratio A is a parameter that can objectively evaluate the fineness of the pattern.

[0049]

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 satin pattern becomes rougher toward the right side from the left side in Fig. 3. It can be understood that, as the satin pattern becomes rougher, the intensity at the center of the spatial frequency spectrum image is higher, and the intensity ratio A is larger.

[0050]

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.

[0051]

In the hot-dip plated layer of the present embodiment, it is necessary for one or more of the ratios (A/A_{ave}) of the intensity ratio A of each of the five measurement areas to the average value A_{ave} to be 0.50 to 0.65 or 1.45 to 2.00. This means that the ratio (A/A_{ave}) of the intensity ratio A of each measurement area is away from the average value A_{ave} . Such a hot-dip plated layer has a state in which an area showing a relatively fine

satin pattern and an area showing a relatively rough satin pattern are mixed. In this manner, the hot-dip plated layer in which an area showing a relatively fine satin pattern and an area showing a rough satin pattern are mixed has a disordered appearance as a whole, and even if physical defects such as abrasion defects and scratch marks occur on the surface of the plating layer, the defects are less conspicuous. When the ratio

(A/A_{ave}) of the intensity ratio A of each of the five measurement areas to the average

value A_{ave} is outside a range of 0.50 to 0.65 or 1.45 to 2.00, the appearance uniformity is

improved, but defects are more conspicuous. The ratio (A/A_{ave}) may be 0.50 to 0.60 or 0.50 to 0.55. In addition, the ratio (A/A_{ave}) may be 1.55 to 2.00 or 1.70 to 2.00. When the ratio (A/A_{ave}) in the five measurement areas is further from 1.00, defects are less conspicuous.

5 [0052]

Next, a method of producing a hot-dip plated steel sheet of the present 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
10 electromagnetic vibration device 5 disposed above the wiping nozzle 4, a cooling device 6 disposed above the electromagnetic vibration device 5, and a top roller 7 disposed above the cooling device 6.

[0053]

15 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 one or more of the group consisting of Ni, Ti, Zr, and Sr. In addition, the hot-dip plating bath may contain a total of 0.0001 to 2
20 mass% of one or more of the group consisting 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
25 of the hot-dip plating bath 2 is within this range, a desired hot-dip plated layer can be

formed.

[0054]

The electromagnetic vibration device 5 vibrates the steel sheet with a magnetic force, and applies a magnetic force to a conveyed steel sheet 1 and vibrates the steel sheet

5 1. As the electromagnetic vibration device 5, for example, a general electromagnetic vibration control device can be used. The electromagnetic damping device originally prevents the steel sheet from vibrating, and includes a pair of electromagnets that are symmetrically disposed on both sides of a traveling steel sheet 1 at a predetermined distance (for example, 40 to 60 mm), and more desirably, two or more electromagnets on
10 one side in the plate width direction and a non-contact type steel band position detector.

The electromagnetic damping device minimizes vibration of the steel sheet by controlling the attractive force of each electromagnet by a control device based on the detection signal of the position detector, and can also amplify vibration by performing control opposite to the normal control. In the present embodiment, the electromagnetic

15 damping device is used as the electromagnetic vibration device 5, and the steel sheet that has passed through the plating bath is vibrated so that the waviness is applied in the plate width direction. It is desirable that the electromagnetic vibration 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

20 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 1 (the maximum amplitude of the steel sheet in the cooling device) out of the electromagnetic vibration device 5 to be 60 mm or more. In addition, it is desirable to operate the electromagnetic damping

25 device 5 in a range of 0.07 to 0.09 T.

[0055]

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).

[0056]

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.

[0057]

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 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.

[0058]

Next, as shown in Fig. 4, the steel sheet 1 is vibrated by the electromagnetic vibration device 5 and the steel sheet 1 is introduced into the cooling device 6. The steel sheet 1 that is vibrated by the electromagnetic vibration 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 the steel sheet 1 is vibrated, the distance between the injection nozzle and the steel sheet 1 changes irregularly, and thereby, the refrigerant is ununiformly applied over the entire hot-dip plated layer, and the cooling speed on the hot-dip plated layer varies over the entire surface of the hot-dip plated layer. Therefore, the metal structure and alloy composition of the hot-dip plated layer after solidification vary and the appearance pattern of the hot-dip plated layer becomes disordered so that defects are less conspicuous in the appearance. 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. In this case, since the electromagnetic damping device is separated from the cooling device 6 and minimizes vibration of the steel sheet 1, it is not possible to obtain an appearance in which defects are less conspicuous.

[0059]

According to the hot-dip plated steel sheet of the present embodiment, since at least one 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 0.50 to 0.65 or 1.45 to 2.00, even if physical defects occur, the defects are less conspicuous. In addition, in the hot-dip plated steel sheet of the present embodiment, since the average composition of the hot-dip plated layer contains 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]

[0060]

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 vibrating the steel sheet with an electromagnetic vibration device. Here, as shown in Table 1A, the electromagnetic vibration 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, directly below the cooling device in the column of the vibration device position means that “vibration 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 shows the maximum amplitude of the steel sheet in the cooling device. Accordingly, Nos. 1 to 54 of hot-dip plated steel sheets shown in Table 1A and Table 1B were produced.

[0061]

In addition, Nos. 55 and 56 of hot-dip plated steel sheets were produced in the same manner as in Nos. 1 to 54 of hot-dip plated steel sheets except that the steel sheet was not vibrated by the electromagnetic vibration device.

[0062]

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 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.

[0063]

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 S_{25} of intensities of spatial frequencies 1 to 25 and a sum S_5 of intensities of spatial frequencies 1 to 5 were calculated, and a ratio (S_5/S_{25}) of the intensity sum S_5 to the intensity sum S_{25} 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 Table 1B. In Table 1B, “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.

[0064]

When at least one of the ratios (A/A_{ave}) in the five measurement areas was 0.50 to 0.65 or 1.45 to 2.00, it was evaluated as F indicating disordered patterns and less conspicuous defects, and when none of the ratios (A/A_{ave}) in the five measurement areas was 0.50 to 0.65 or 1.45 to 2.00, it was evaluated as P indicating uniform appearance and

more conspicuous defects. F was satisfactory, and P was unsatisfactory. The results are shown in Table 1B.

[0065]

In addition, the inconspicuousness of defects was visually evaluated. The
5 plating appearance was visually evaluated. After abrasion defects were made, when the abrasion defects were not visible from 3 m ahead, it was evaluated as F indicating good inconspicuousness of defects, and when abrasion defects were visible, it was evaluated as P indicating insufficient inconspicuousness of defects. F was satisfactory, and P was unsatisfactory. The results are shown in Table 1B.

10 [0066]

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
15 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. The results are shown in Table 1B.

[0067]

20 As shown in Table 1A and Table 1B, No. 1 to No. 46 of hot-dip plated steel sheets of the examples of the present invention had less conspicuous defects and excellent corrosion resistance.

[0068]

On the other hand, as shown in Table 1A and Table 1B, No. 47 to No. 56 of hot-
25 dip plated steel sheets of comparative examples had conspicuous defects or poor

corrosion resistance.

[0069]

In addition, regarding the evaluation of the inconspicuousness of defects, a sufficient correlation was observed between evaluation using the ratio (A/A_{ave}) according to the present invention and visual evaluation.

5

[0070]

[Table 1A]

No.	Production method			Hot-dip plated layer				
	Production method	Vibration 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	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	-	280
2	Vibrate steel sheet	Directly below cooling device	80	2	2.0	-	-	280
3	Vibrate steel sheet	Directly below cooling device	70	3	2.0	-	-	270
4	Vibrate steel sheet	Directly below cooling device	70	4	3.0	-	-	310
5	Vibrate steel sheet	Directly below cooling device	80	5	3.0	-	-	260
6	Vibrate steel sheet	Directly below cooling device	70	6	3.0	-	-	280
7	Vibrate steel sheet	Directly below cooling device	80	16	3.0	0.4	-	270
8	Vibrate steel sheet	Directly below cooling device	90	18	3.0	0.4	-	290
9	Vibrate steel sheet	Directly below cooling device	70	22	3.0	0.2	-	380
10	Vibrate steel sheet	Directly below cooling device	70	2	0.1	-	-	260
11	Vibrate steel sheet	Directly below cooling device	80	6	0.8	-	-	270
12	Vibrate steel sheet	Directly below cooling device	70	11	1.0	0.2	-	200
13	Vibrate steel sheet	Directly below cooling device	90	11	1.5	0.2	-	360

14	Vibrate steel sheet	Directly below cooling device	80	11	2.0	0.2	-	-	300
15	Vibrate steel sheet	Directly below cooling device	80	11	5.0	0.2	-	-	280
16	Vibrate steel sheet	Directly below cooling device	70	11	6.0	0.2	-	-	270
17	Vibrate steel sheet	Directly below cooling device	90	11	10	0.2	-	-	310
18	Vibrate steel sheet	Directly below cooling device	90	11	3.0	0.0001	-	-	260
19	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.8	-	-	310
20	Vibrate steel sheet	Directly below cooling device	80	17	3.0	1	-	-	290
21	Vibrate steel sheet	Directly below cooling device	70	22	3.0	2	-	-	350
22	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Ni	0.1	260
23	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Ti	0.01	200
24	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	Zr	0.0001	290
25	Vibrate steel sheet	Directly below cooling device	90	11	3.0	0.2	Sr	0.01	290
26	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Fe	0.01	180
27	Vibrate steel sheet	Directly below cooling device	110	11	3.0	0.2	Sb	0.01	70
28	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	Pb	0.01	30
29	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Sn	0.01	450
30	Vibrate steel sheet	Directly below cooling device	90	11	3.0	0.2	Ca	0.01	300
31	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Co	0.01	400

32	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Mn	0.01	320
33	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	P	0.01	200
34	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	B	0.0001	280
35	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	Bi	0.01	300
36	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	Cr	0.01	400
37	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	Sc	0.01	300
38	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Y	0.01	80
39	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	REM	0.01	310
40	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	Hf	0.01	60
41	Vibrate steel sheet	Directly below cooling device	60	11	3.0	0.2	-	-	280
42	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	-	-	280
43	Vibrate steel sheet	Directly below cooling device	80	11	3.0	0.2	-	-	290
44	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	-	-	280
45	Vibrate steel sheet	Directly below cooling device	70	11	3.0	0.2	-	-	290
46	Vibrate steel sheet	Directly below cooling device	60	11	3.0	0.2	-	-	300
47	Vibrate steel sheet	Directly below cooling device	70	<u>1</u>	2.0	-	-	-	270
48	Vibrate steel sheet	Directly below cooling device	80	<u>23</u>	3.0	0.4	-	-	280
49	Vibrate steel sheet	Directly below cooling device	80	6	-	-	-	-	270

50	Vibrate steel sheet	Directly below cooling device	70	11	11	0.2	-	-	320
51	Vibrate steel sheet	Directly below wiping	55	11	3.0	0.2	-	-	310
52	Vibrate steel sheet	Position of 3 m below cooling device	50	11	3.0	0.2	Sn	0.01	600
53	Vibrate steel sheet	Position of 3 m below cooling device	45	11	3.0	0.2	-	-	290
54	Vibrate steel sheet	Position of 3 m below cooling device	55	11	3.0	0.2	-	-	270
55	Without vibrating steel sheet	-	45	11	3.0	0.2	-	-	290
56	Without vibrating steel sheet	-	50	11	3.0	0.2	-	-	300

Underlined parts indicate values outside the scope of the present invention.
[0071]

[Table 1B]

No.	Hot-dip plated layer						Evaluation			Note
	Average value A_{ave}	Ratio (A/A_{ave})				Conspicuousness of defects		Corrosion resistance		
		Upper left corner	Upper right corner	Center	Lower left corner	Lower right corner	Evaluation according A/A_{ave}		Visual evaluation	
1	0.12	1.70	1.04	0.74	0.80	0.72	F	F	F	Example of invention
2	0.13	0.81	1.54	1.05	0.92	0.68	F	F	P	
3	0.11	1.61	0.82	0.71	1.02	0.84	F	F	P	
4	0.11	0.83	0.82	0.77	1.68	0.90	F	F	G	
5	0.12	0.75	0.82	1.74	0.78	0.91	F	F	F	
6	0.11	0.89	0.70	0.75	1.56	1.10	F	F	F	
7	0.14	1.23	0.55	0.83	1.25	1.14	F	F	F	
8	0.18	1.00	1.15	1.11	0.58	1.16	F	F	F	

Example of invention

9	0.18	0.97	1.25	1.10	0.56	1.12	F	F	G
10	0.12	0.64	1.25	1.15	1.10	0.86	F	F	P
11	0.10	0.83	0.84	1.58	0.81	0.94	F	F	P
12	0.10	1.57	0.86	0.78	0.82	0.97	F	F	G
13	0.11	0.80	0.96	0.80	0.83	1.61	F	F	F
14	0.12	1.21	1.24	1.12	0.57	0.86	F	F	F
15	0.13	0.73	1.02	0.72	1.66	0.87	F	F	F
16	0.14	0.98	1.17	0.58	1.29	0.98	F	F	F
17	0.19	1.07	1.06	0.50	1.17	1.20	F	F	G
18	0.10	0.81	0.77	1.72	0.80	0.90	F	F	F
19	0.14	0.72	1.68	0.97	0.86	0.77	F	F	F
20	0.19	0.52	1.31	0.85	1.24	1.08	F	F	F
21	0.18	0.98	0.97	0.76	0.72	1.57	F	F	F
22	0.11	0.81	0.91	1.61	0.86	0.81	F	F	F
23	0.19	1.06	0.59	1.29	1.13	0.93	F	F	F
24	0.12	0.78	0.83	1.56	0.97	0.86	F	F	F
25	0.13	0.69	1.73	0.87	0.79	0.92	F	F	F
26	0.15	1.15	1.18	1.20	0.92	0.55	F	F	F
27	0.12	0.68	1.79	1.45	0.50	0.58	F	F	F
28	0.12	0.90	0.78	0.89	1.57	0.86	F	F	F
29	0.15	0.89	0.80	1.60	0.78	0.93	F	F	F
30	0.17	0.55	1.04	0.99	1.21	1.21	F	F	F
31	0.14	0.83	0.86	0.89	0.71	1.71	F	F	F
32	0.19	1.08	1.27	0.98	0.59	1.08	F	F	F
33	0.11	0.84	0.78	1.68	0.91	0.79	F	F	F
34	0.14	0.73	1.22	1.57	0.73	0.75	F	F	F
35	0.10	1.29	0.70	0.73	0.72	1.56	F	F	F
36	0.12	0.76	0.91	0.85	0.86	1.62	F	F	F
37	0.13	0.86	1.58	0.76	0.68	1.12	F	F	F
38	0.15	1.24	1.00	1.26	0.55	0.95	F	F	F
39	0.16	1.09	0.57	1.17	1.09	1.08	F	F	F
40	0.14	0.99	1.12	0.57	1.27	1.05	F	F	F
41	0.12	1.13	0.65	1.07	1.10	1.05	F	F	F
42	0.17	0.87	1.23	0.97	1.29	0.64	F	F	F
43	0.15	1.10	0.59	0.75	1.28	1.28	F	F	F

44	0.16	1.55	0.79	0.77	1.14	0.75	F	F	Comparative Example
45	0.16	0.95	1.50	0.77	1.04	0.74	F	F	
46	0.14	1.02	0.76	0.89	1.45	0.88	F	F	
47	0.15	1.35	0.64	0.70	1.11	1.20	F	X	
48	0.19	1.09	0.91	0.71	1.57	0.72	F	X	
49	0.13	1.52	0.79	0.92	0.71	1.06	F	X	
50	0.17	1.11	0.53	1.12	1.11	1.13	F	X	
51	0.10	0.98	0.72	1.42	0.72	1.16	P	F	
52	0.13	<u>0.72</u>	<u>1.43</u>	<u>0.71</u>	<u>1.42</u>	<u>0.72</u>	P	F	
53	0.12	<u>0.96</u>	<u>1.23</u>	<u>0.97</u>	<u>0.69</u>	<u>1.15</u>	P	F	
54	0.18	<u>0.86</u>	<u>1.40</u>	<u>0.81</u>	<u>0.70</u>	<u>1.23</u>	P	F	
55	0.15	<u>0.88</u>	<u>1.32</u>	<u>0.68</u>	<u>1.02</u>	<u>1.10</u>	P	F	
56	0.17	<u>1.43</u>	<u>0.87</u>	<u>0.92</u>	<u>0.95</u>	<u>0.83</u>	P	F	

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 an average composition of the hot-dip plated layer contains 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 for each measurement area are obtained by a following measurement method, at least one ratio (A/A_{ave}) of an
10 intensity ratio A of each measurement area to an average value A_{ave} of the intensity ratios A of the five measurement areas is 0.50 to 0.65 or 1.45 to 2.00, 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 the intensity ratio A.

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

wherein the average composition of the hot-dip plated layer contains Al: 4 to 22 mass%, and Mg: 1.0 to 10 mass%.

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

25 wherein the average composition of the hot-dip plated layer further contains Si:

0.0001 to 2 mass%.

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

wherein the average composition of the hot-dip plated layer further contains a

5 total of 0.0001 to 2 mass% of one or more of a group consisting of Ni, Ti, Zr, and Sr.

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

wherein the average composition of 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,

10 Co, Mn, P, B, Bi, Cr, Sc, Y, REM, and Hf.

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.