

[Document Type] Specification

[Title of the Invention] HOT-DIPPED CHECKERED STEEL PLATE AND
MANUFACTURING METHOD THEREOF

[Technical Field of the Invention]

[0001]

The present invention relates to a hot-dipped checkered steel plate and a manufacturing method thereof.

Priority is claimed on Japanese Patent Application No. 2017-178011, filed on September 15, 2017, the content of which is incorporated herein by reference.

[Related Art]

[0002]

A checkered steel plate is a steel plate having a continuous non-slip projection (raised portion) on a surface thereof by rolling. In general, raised portions having a certain width, a certain length, and a certain height are provided at a certain angle and a certain pitch with respect to a rolling direction. A checkered steel plate is usually manufactured by hot rolling. The checkered steel plate is used for floorboards and steps of buses and trucks or the like, bottom boards of factories, decks of ships, temporary scaffolds or stairs in construction sites, or the like.

[0003]

In many cases, a checkered steel plate has been used as hot rolled or coated. Particularly, in a case where an antirust property was required, a cut plate of a checkered steel plate was galvanized through a batch type hot-dip galvanizing process using a flux method. However, the batch type hot-dip galvanizing process has low productivity. Moreover, since a Fe-Zn alloy layer produced in the hot-dip coating step may be enlarged, the workability of the coating layer may be impaired, plating

cracks or peeling may occur in the coating layer, and thus a problem may occur in corrosion resistance.

[0004]

Continuous hot-dip galvanizing has higher productivity than batch type hot-dip galvanizing. In general, continuous hot-dip galvanizing is performed by passing a steel plate heated to a predetermined temperature in a reducing or non-oxidizing atmosphere through a molten zinc bath. In addition, since the molten zinc bath contains at least about 0.05% of Al, the growth of the Fe-Zn alloy layer impairing the workability of the coating film can be suppressed. In general batch type hot-dip galvanizing using a flux method, in a case where a Zn bath contains Al, Al decomposes the flux, and thus unplating occurs frequently and plating cannot be performed well.

[0005]

In a case where a checkered steel plate is subjected to continuous hot-dip galvanizing, it is necessary to consider a problem caused by a surface shape or the like of the checkered steel plate. For example, Patent Document 1 discloses a continuous hot-dip galvanizing method for a strip-shaped checkered steel plate, and particularly, appropriate conditions for tension in a plating line and gas wiping after hot-dip coating. At present, continuous hot-dip galvanized checkered steel plate has been commercialized.

[0006]

In recent years, in addition to a hot-dip galvanized steel plate, hot-dip zinc-based alloy (such as Zn-Al, Zn-Al-Mg, or Zn-Al-Mg-Si) plated steel plates have been developed and commercialized due to demand for more excellent corrosion resistance than in galvanizing. In response to this, attempts have also been made to apply hot-dip zinc-based alloy plating to a checkered steel plate.

[0007]

Patent Document 2 discloses a checkered steel plate which is excellent in workability and corrosion resistance and has a Ni-Al-Zn-Fe quaternary alloy layer with a thickness of 2 μm or less as a primary layer and a hot-dip coating layer of a Zn-based alloy containing 0.1% to 1% of Al in terms of weight as a secondary layer on a surface of the checkered steel plate. As a specific plating method, Patent Document 2 discloses a manufacturing method of a checkered steel plate including the steps of: subjecting a checkered steel plate to Ni plating of 0.5 to 2.0 g/m^2 ; heating the checkered steel plate; and dipping the checkered steel plate in a molten zinc bath containing 0.1% to 1% of Al added thereto in terms of weight for a dipping time of 1 to 30 seconds.

[0008]

In Patent Document 3, a coating bath which is considered to be substantially the same as in Patent Document 2 is used, and a structure of a hot-dip coating film obtained by the Sendzimir method is defined. Both Patent Documents 2 and 3 are essentially characterized in that a hot-dip zinc-based alloy with an Al concentration of 1% or less is used. In Patent Documents 2 and 3, since the Al concentration in the coating layer is 1% or less, a barrier anticorrosive effect due to Al is hardly obtained, and it is not possible to expect a preferable significant improvement in corrosion resistance of the coating film itself.

[0009]

Patent Document 4 discloses a hot-dip zinc-based coating checkered steel plate which is excellent in scratch resistance, wear resistance, and corrosion resistance and is coated with a hot-dip coating layer containing, as a composition, by mass%, Al: 4.0% to 20.0%, Mg: 1.0% to 4.0%, and optionally, Ti: 0.002% to 0.1% and B: 0.001%

to 0.045% with a remainder consisting of Zn and inevitable impurities. In the coating layer, the existence ratio of the ternary eutectic microstructure of the Al/Zn/ZnMg-based intermetallic compound is high, and the ternary eutectic is hard. Accordingly, the coating layer has a Vickers hardness of 120 to 180 Hv, and is also excellent in scratch resistance and wear resistance in addition to corrosion resistance.

[0010]

As described above, a checkered steel plate has been used without being plated in many cases, and optionally galvanized. Instead of Zn plating, zinc-based alloy plating has also been attempted. Ni pre-plating of a base steel plate and zinc-based alloy plating with an Al concentration more than 1.0% after Ni pre-plating have not been considered at all.

[Prior Art Document]

[Patent Document]

[0011]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. H7-11411

[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. H6-81170

[Patent Document 3] Japanese Unexamined Patent Application, First Publication No. H6-248409

[Patent Document 4] Japanese Unexamined Patent Application, First Publication No. H11-279732

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0012]

The inventors performed zinc-based alloy plating with an Al concentration more than 1.0% on a checkered steel plate as an attempt to further improve corrosion resistance of the checkered steel plate. However, as a result of examination, it has been found that performing zinc-based alloy plating with an Al concentration more than 1.0% on the checkered steel plate causes frequently unplating. That is, it has been found that, for example, as disclosed in Patent Documents 2 and 3, in a case where the Al concentration of the zinc-based alloy plating is 1.0% or less, the occurrence of unplating does not become a problem, but for example, as disclosed in Patent Document 4, in a case where the Al concentration of the zinc-based alloy plating is more than 1.0%, the occurrence of unplating becomes a problem.

[0013]

Specifically, first, the inventors considered performing Zn-based alloy plating containing more than 1.0% of Al and a slight amount of Mg, that is generally said to provide more excellent corrosion resistance than usual Zn plating, on a checkered steel plate in order to impart excellent corrosion resistance to the checkered steel plate. In the process, the inventors have found that unplating occurs frequently in a case where the checkered steel plate is subjected to hot-dip coating of a Zn-Al-Mg-based alloy with an Al concentration more than 1.0% by the Sendzimir method which is usually employed as a hot-dip coating method.

[0014]

The inventors have thought that the reason why unplating is likely to occur during the course of subjecting the checkered steel plate to hot-dip coating of a Zn-based alloy containing Al: more than 1.0% and a slight amount of Mg is related to the fact that the higher the Al concentration in the molten Zn, the lower the wettability between the steel plate and the molten metal, and is also related to a specific cause due

to the hot rolling history of the checkered steel plate.

[0015]

The inventors employed Ni pre-plating, which is also employed in Patent Document 2, as an attempt to solve the problem of unplating. As a result of examination, the inventors have found that although the occurrence of unplating can be suppressed to some extent by performing zinc-based alloy plating after Ni pre-plating, it is necessary to relatively increase the adhesion amount of Ni in the Ni pre-plating in a case where zinc-based alloy plating with an Al concentration more than 1.0% is performed on the checkered steel plate. However, as a result of the above examination, the inventors have also found that in a case where the adhesion amount of Ni in the Ni pre-plating is increased, the corrosion resistance is likely to decrease at a raised portion when the hot-dipped checkered steel plate is worn.

[0016]

That is, regarding the application of zinc-based alloy plating with an Al concentration of more than 1.0% to a checkered steel plate in order to further improve corrosion resistance, the inventors have found the following:

(a) Only performing that zinc-based alloy plating with an Al concentration more than 1.0% on the checkered steel plate causes frequently unplating.

(b) In order to perform zinc-based alloy plating with an Al concentration of more than 1.0% on the checkered steel plate, Ni pre-plating is required, and it is necessary to increase the adhesion amount of Ni compared to the related art.

(c) However, in a case where the adhesion amount of Ni to the checkered steel plate is increased in the Ni pre-plating, the corrosion resistance is likely to decrease at a raised portion when the hot-dipped checkered steel plate is worn.

[0017]

The inventors thought about the above phenomenon as follows. For example, in a case where a hot-dipped checkered steel plate is used for a floorboard or the like, a hot-dip coating layer may be significantly worn at a raised portion thereof, and a Ni coating layer may be exposed. In a case where a steel plate subjected to Ni pre-plating is plated with molten Zn or molten Zn-Al, a part of Ni moves to the coating layer or the molten metal due to a reaction with the molten metal, but a part of Ni remains on a surface of the steel plate as a Ni coating layer. Therefore, in a case where the adhesion amount of Ni in the Ni pre-plating is large, the Ni coating layer remaining on the surface of the steel plate after hot-dip coating is increased.

[0018]

In general, the corrosion potential inclines from high to low in order of Ni, Fe, and the coating layer, but the corrosion potential of a Ni coating layer which is relatively thin is a mixed potential of Ni and Fe. In hot-dip coating of a Zn-based alloy subjected to Ni pre-plating, in a case where a hot-dip coating layer of the Zn-based alloy of the upper layer is worn and a Ni coating layer is exposed, Galvanic corrosion occurs between the exposed portion and the vicinity of the exposed portion. For example, in a hot-dipped checkered steel plate, Galvanic corrosion occurs between a Ni coating layer exposed at a raised portion and a hot-dip coating layer in the vicinity of the exposed portion. In a case where the Ni coating layer is thin even when being exposed, the corrosion potential of the Ni coating layer becomes a mixed potential and approaches the potential of Fe, and the Galvanic corrosion rate between the Ni coating layer and the hot-dip coating layer is not high. On the other hand, in a case where the Ni coating layer is thick, the corrosion potential of the Ni coating layer is substantially close to the potential of Ni even in a case where it is a mixed potential, and thus the Galvanic corrosion rate between the Ni coating layer and the hot-dip coating layer is

high. As a result, the hot-dip coating layer is easily corroded and worn.

[0019]

Hereinafter, in order to prevent confusion, in the present specification, in a case where “Ni coating layer” or “Ni plating” is used to express a coating layer, it means a Ni cover layer remaining after hot-dip coating, and “Ni pre-coating layer” or “Ni pre-plating” means a Ni cover layer existing before the hot-dip coating step, unless otherwise specified. In the following description of the present specification, in a case where an expression such as “hot-dip coating of a Zn-based alloy” or “hot-dip coating” means “hot-dip coating of a Zn-Al-Mg-based alloy”.

[0020]

An object of the present invention is to provide a hot-dipped checkered steel plate and the manufacturing method thereof which is a checkered steel plate subjected to hot-dip coating of a Zn-Al-Mg-based alloy containing more than 1.0% of Al, which is little unplated, and exhibits excellent corrosion resistance even in a case where the hot-dip coating of the Zn-based alloy is worn (corroded or worn) at a raised portion of the checkered steel plate. Another object of the present invention is to provide a hot-dipped checkered steel plate and the manufacturing method thereof which satisfies general characteristics required for the hot-dipped checkered steel plate, such as plating appearance and workability, and can achieve both suppression of the unplating described above and corrosion resistance after wear.

[Means for Solving the Problem]

[0021]

The inventors have thought that in a case where a checkered steel plate subjected to Ni pre-plating is subjected to hot-dip coating of a Zn-Al-Mg-based alloy containing more than 1.0% of Al, a relatively large adhesion amount of Ni is required

from the viewpoint of preventing unplating, but from the viewpoint of securing the corrosion resistance at a raised portion of the checkered steel plate, it is necessary to suppress at least the adhesion amount of Ni at the raised portion to a certain value or less.

[0022]

Electro plating is usually employed in performing Ni pre-plating on a steel strip. An electroless method may be used to precipitate Ni on the steel strip. However, the electroless method is not preferable since productivity deteriorates and elements other than Ni are mixed in a large amount into the precipitated coating. Usually, in a case where electro plating is performed on a general steel strip, an anode is disposed to be opposed to a surface of the steel strip serving as a cathode, and the distance between electrodes between the steel strip and the anode is made as short as possible to perform electrolysis, so that uniformity of current distribution is secured, and the power cost is suppressed.

[0023]

However, in a case where electro plating is performed on a checkered steel plate, the distance between electrodes between a raised portion of the checkered steel plate and the anode is shorter than that between a flat portion of the checkered steel plate and the anode, and thus the adhesion amount of Ni is increased at the raised portion of the checkered steel plate. That is, in a case where Ni pre-plating is performed on a checkered steel plate by electro plating in a normal electrolytic cell under conventional conditions, the adhesion amount of Ni at a raised portion is significantly increased, and as a result, there is a concern that severe Galvanic corrosion may occur at the raised portion when the hot-dip coating layer of the hot-dipped checkered steel plate is worn.

[0024]

The inventors have found that the above problems can be solved by determining, regarding a checkered steel plate subjected to hot-dip coating of a Zn-Al-Mg-based alloy containing more than 1.0% of Al, a lower limit value of the thickness of a Ni pre-coating layer required for preventing unplating and an upper limit value of the thickness of a Ni coating layer to be limited to secure corrosion resistance at a raised portion, and by defining a ratio of the thickness of the Ni coating layer of the raised portion to the thickness of the Ni coating layer of the flat portion.

[0025]

The gist of the present invention is as follows.

(1) A hot-dipped checkered steel plate according to an aspect of the present invention comprising: a base steel plate; a Ni coating layer which is disposed on a surface of the base steel plate; and a hot-dip coating layer which is disposed on a surface of the Ni coating layer, in which a raised portion and a flat portion are provided on the surface of the base steel plate, a film thickness of the Ni coating layer of the raised portion is 0.07 to 0.4 μm per surface, a film thickness of the Ni coating layer of the flat portion is 0.05 to 0.35 μm per surface, the film thickness of the Ni coating layer of the raised portion is more than 100% and 400% or less of the film thickness of the Ni coating layer of the flat portion, an adhesion amount of the hot-dip coating layer is 60 to 400 g/m^2 per surface, and the hot-dip coating layer contains, as a chemical composition, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities.

(2) In the hot-dipped checkered steel plate according to (1), the film thickness of the Ni coating layer of the raised portion may be more than 100% and 300% or less

of the film thickness of the Ni coating layer of the flat portion.

(3) In the hot-dipped checkered steel plate according to (1) or (2), the film thickness of the Ni coating layer of the raised portion may be 0.07 to 0.3 μm per surface.

(4) In the hot-dipped checkered steel plate according to any one of (1) to (3), the hot-dip coating layer may contain, as a chemical composition, by mass%, Al: 4.0% to 25.0% and Mg: 1.5% to 8.0%.

(5) In the hot-dipped checkered steel plate according to any one of (1) to (4), the hot-dip coating layer may contain, as a chemical composition, by mass%, at least one selected from the group consisting of Si: 0.05% to 1.0%, Sn: 0.1% to 3.0%, or Ca: 0.01% to 1.0%.

(6) In the hot-dipped checkered steel plate according to any one of (1) to (5), a coverage of the hot-dip coating layer may be 99% to 100% by area% with respect to the surface of the base steel plate when viewed from a thickness direction.

(7) A manufacturing method of the hot-dipped checkered steel plate according to an aspect of the present invention which is a manufacturing method of the checkered steel plate according to any one of (1) to (6), including: a rolling step of providing a raised portion and a flat portion on a rolled surface of the steel plate; a pre-plating step of performing Ni pre-plating on the steel plate subjected to the rolling step; and a hot-dip coating step of performing hot-dip coating on the steel plate subjected to the pre-plating step, in which in the pre-plating step, electro Ni plating is performed under conditions in which the rolled surface of the steel plate and an anode surface are disposed to be opposed to each other, a distance between electrodes between the raised portion of the rolled surface and the anode is controlled to be 40 to 100 mm, and an adhesion amount of plating per surface is 0.5 to 3 g/m^2 on average, and in the hot-dip

coating step, the steel plate is heated, dipped in a hot-dip coating bath containing, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities, and subjected to continuous hot-dip coating under conditions in which an adhesion amount of plating per surface is 60 to 400 g/m² on average.

(8) In the manufacturing method of the hot-dipped checkered steel plate according to (7), in the pre-plating step, the distance between electrodes may be controlled to 45 to 100 mm.

[Effects of the Invention]

[0026]

According to the aspect of the present invention, since the hot-dip coating layer contains more than 1.0% of Al, excellent corrosion resistance is obtained. In addition, since the film thickness of the Ni coating layer is controlled, the occurrence of unplating can be suppressed, and corrosion when the hot-dip coating layer is worn and the Ni coating layer is exposed can also be suppressed. As a result, the life-cycle cost of floorboards, bottom boards, structures, and the like as the hot-dipped checkered steel plate can be suppressed.

[Brief Description of the Drawings]

[0027]

FIG. 1A is a schematic view when a base steel plate of a hot-dipped checkered steel plate according to an embodiment of the present invention is viewed from a thickness direction.

FIG. 1B is a cross-sectional view taken along line G-G of FIG. 1A, which is a schematic cross-sectional view when the base steel plate of the hot-dipped checkered steel plate according to the embodiment is viewed in a cut surface where the thickness

direction and the cutting direction are parallel to each other.

FIG. 1C is a cross-sectional view taken along line F-F of FIG. 1A, which is a schematic cross-sectional view when the base steel plate of the hot-dipped checkered steel plate according to the embodiment is viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other.

FIG. 2 is a schematic cross-sectional view when the hot-dipped checkered steel plate according to the embodiment is viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other.

[Embodiments of the Invention]

[0028]

Hereinafter, preferable embodiments of the present invention will be described in detail. The present invention is not limited only to the configuration disclosed in this embodiment, and various changes can be made without departing from the purpose of the present invention. A lower limit value and an upper limit value are included in a numerical limit range to be described below. A numerical value expressed by “more than” or “less than” is not included in the numerical value range.

[0029]

A hot-dipped checkered steel plate according to this embodiment has a base steel plate, a Ni coating layer disposed on a surface of the base steel plate, and a hot-dip coating layer of a Zn-based (Zn-Al-Mg-based) alloy disposed on a surface of the Ni coating layer, and has a raised portion and a flat portion on a surface of the base steel plate thereof. The film thickness of the Ni coating layer of the raised portion is 0.07 to 0.4 μm per surface, the film thickness of the Ni coating layer of the flat portion is 0.05 to 0.35 μm per surface, and the film thickness of the Ni coating layer of the

raised portion is more than 100% and 400% or less of the film thickness of the Ni coating layer of the flat portion. The adhesion amount of the hot-dip coating layer is 60 to 400 g/m² per surface, and the hot-dip coating layer contains, as a chemical composition, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities.

[0030]

A thin intermetallic compound layer based on a reaction between a molten metal (a hot-dip coating bath of a Zn-based alloy) and the steel plate subjected to Ni pre-plating may be formed on the Ni coating layer side of the hot-dip coating layer, and the composition thereof varies with the composition of the hot-dip coating bath of the Zn-based alloy. In this embodiment, the “hot-dip coating layer of the Zn-based alloy” is used in the meaning including the intermetallic compound layer.

[0031]

First, the hot-dip coating layer of the hot-dipped checkered steel plate according to this embodiment will be described in detail.

[0032]

The hot-dip coating layer is a Zn-based alloy and contains, as a chemical composition, Al: more than 1.0% and 26% or less and Mg: 0.05% to 10% by mass%.

[0033]

Al (aluminum) is important for securing the corrosion resistance of the hot-dip coating layer. In addition, Al prevents oxidation of the molten metal and suppresses the generation of Fe-Zn-based dross. Therefore, the Al concentration of the hot-dip coating layer is controlled to exceed 1.0%. In a case where the Al concentration of the coating bath is increased, the melting point increases, and thus it is

necessary to increase the temperature of the molten metal. In addition, in a case where the Al concentration is more than 26%, it is difficult to secure the beautiful surface properties of the coating layer, and workability is likely to decrease.

Therefore, the Al concentration of the hot-dip coating layer is 26% or less. From the viewpoint of corrosion resistance, the Al concentration of the hot-dip coating layer is preferably controlled to 4.0% or more. From the viewpoint of workability, the Al concentration of the hot-dip coating layer is preferably 25.0% or less, and more preferably 21.0% or less.

[0034]

Mg (magnesium) forms a barrier layer against corrosion by forming a stable corrosion product in a corrosive environment, and improves corrosion resistance. In a case where the Mg concentration is less than 0.05%, this effect is degraded.

Therefore, the Mg concentration in the hot-dip coating layer is controlled to be 0.05% or more. The higher the Mg concentration in the molten metal, the further the oxidation of the molten metal is promoted. Therefore, the Mg concentration in the hot-dip coating layer is controlled to be 10% or less. In a case where the Mg concentration is more than 10%, it is difficult to secure the beautiful surface properties of the coating layer, including the influence of an increase in the amount of oxide dross generated. A lower limit of the Mg concentration is preferably 0.5%, more preferably 1%, even more preferably 1.5%, and still more preferably 2.0%. An upper limit of the Mg concentration is preferably 8.5%, more preferably 8.0%, and even more preferably 6.0%.

[0035]

The hot-dip coating layer of the hot-dipped checkered steel plate according to this embodiment contains, as a chemical composition, Al and Mg, which are the basic

elements described above, with a remainder consisting of Zn and impurities. For example, in the hot-dip coating layer, the Zn concentration is 64% to 98.95% by mass%. The hot-dip coating layer may contain, as optional elements, 1.0% or less of Si, 3.0% or less of Sn, and 1.0% or less of Ca by mass%, instead of a part of Zn as the above described remainder.

[0036]

Si (silicon) suppresses the growth of an interface alloy phase formed at the interface with the base steel plate, and contributes to an improvement in workability. In addition, Si suppresses the oxidation of Mg, and also contributes to an improvement in corrosion resistance by forming Mg_2Si with Mg. Therefore, the Si concentration of the hot-dip coating layer may be controlled to 0% to 1.0%. In order to preferably obtain the above effects of Si, Si is contained in an amount of 0.05% or more, and preferably 0.1% or more. In a case where the Si concentration is more than 1.0%, the above effects are saturated. The upper limit of the Si concentration is preferably 0.6%.

[0037]

Sn (tin) forms Mg_2Sn with Mg, and also contributes to an improvement in corrosion resistance, particularly, end surface corrosion resistance. Therefore, the Sn concentration of the hot-dip coating layer may be controlled to 0% to 3.0%. In order to preferably obtain the effects of Sn, Sn is contained in an amount of 0.1% or more, and preferably 0.3% or more. In a case where the Sn concentration is more than 3.0%, the corrosion resistance, particularly, the corrosion resistance of the flat portion is likely to decrease. The upper limit of the Sn concentration is preferably 2.4%.

[0038]

Ca (calcium) is effective for preventing the oxidation of the coating bath

surface. A molten Zn-Al-Mg-based alloy tends to be oxidized more easily than those containing no Mg. By adding Ca, the oxidation of the coating bath surface can be preferably suppressed. Therefore, the Ca concentration of the hot-dip coating layer may be controlled to 0% to 1.0%. The Ca concentration is preferably 0.01% or more, and more preferably 0.1% or more. In a case where the Ca concentration is more than 1.0%, the precipitation of a Ca-based intermetallic compound is increased, and the corrosion resistance, particularly, the corrosion resistance of the flat portion may be reduced. The upper limit of the Ca concentration is preferably 0.7%.

[0039]

Regarding the chemical composition of the hot-dip coating layer, the remainder of the basic elements and the optional elements described above consists of Zn and impurities. The “impurities” refer to those which are mixed from the raw material or the manufacturing environment. For example, in the hot-dip coating layer of the hot-dipped checkered steel plate according to this embodiment, Ni, Fe, and the like dissolve into the coating bath from the surface of the steel plate and become impurities of the Zn-based alloy. For example, the hot-dip coating layer may contain Ni derived from the Ni pre-coating layer, and the Ni concentration may be 0.01% to 0.3% by mass%. In the hot-dip coating layer of the hot-dipped checkered steel plate according to this embodiment, impurities are allowed to be contained within a range that does not impair desired characteristics.

[0040]

A Ni-Al-based intermetallic compound layer may be formed at the interface between the hot-dip coating layer and the Ni coating layer. In this embodiment, the intermetallic compound layer is regarded as a part of the hot-dip coating layer.

[0041]

In this embodiment, the average adhesion amount of the hot-dip coating layer is 60 g/m² or more per surface. The average adhesion amount means an average adhesion amount including the raised portion and the flat portion of the hot-dipped checkered steel plate. That is, the average adhesion amount means the adhesion amount per projected area, ignoring the projecting raised portion of the hot-dipped checkered steel plate. In a case where the average adhesion amount of the hot-dip coating layer is less than 60 g/m², the corrosion resistance is not sufficient. The upper limit of the average adhesion amount of the hot-dip coating layer is not necessarily limited. However, in a case where the hot-dip coating layer is adhered in an excessive amount, dripping of the plating becomes severe and the appearance is impaired. Accordingly, the average adhesion amount of the hot-dip coating layer is preferably controlled to 400 g/m² or less per surface.

[0042]

In this embodiment, when the hot-dipped checkered steel plate is viewed from the thickness direction, the coverage of the hot-dip coating layer is preferably 99% to 100% by area% with respect to the surface of the base steel plate. In a case where the coverage of the hot-dip coating layer is 99% or more by area%, it can be judged that the occurrence of unplating can be preferably suppressed.

[0043]

Next, the Ni coating layer of the hot-dipped checkered steel plate according to this embodiment will be described in detail.

[0044]

The Ni coating layer is a Ni pre-coating layer formed on the surface of the base steel plate to prevent unplating in the hot-dip coating step and remaining between the base steel plate and the hot-dip coating layer even after hot-dip coating.

[0045]

For example, in the observation of a cross section of the hot-dipped checkered steel plate through a reflected electron image of a scanning electron microscope (SEM), the Ni coating layer corresponds to a light region (a range displayed white) observed between the base steel plate and the hot-dip coating layer. In this embodiment, the Ni coating layer does not include a Ni-containing intermetallic compound layer which may be formed at the interface between the Ni coating layer and the base steel plate and a Ni-containing intermetallic compound layer which may be formed at the interface between the Ni coating layer and the hot-dip coating layer.

[0046]

The Ni coating layer contains, as a chemical composition, Ni with a remainder consisting of impurities. For example, the Ni concentration of the Ni coating layer is preferably 50% to 100% by mass%. The “impurities” refer to those which are mixed from the raw material or the manufacturing environment. For example, the Ni coating layer of the hot-dipped checkered steel plate according to this embodiment contains impurities due to diffusion of Fe from the base steel plate.

[0047]

In this embodiment, the film thickness of the Ni coating layer of the raised portion of the hot-dipped checkered steel plate is required to be 0.4 μm or less per surface on average when viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other. In a case where the film thickness is more than 0.4 μm , the corrosion resistance when the hot-dip coating layer of the Zn-based alloy is worn and the Ni coating layer is exposed at the raised portion is reduced. The film thickness of the Ni coating layer of the raised portion is preferably 0.3 μm or less. The lower limit of the film thickness of the Ni coating layer of the raised portion is

0.07 μm or more per surface on average. In a case where the film thickness is less than 0.07 μm , unplating occurs at the raised portion. The film thickness of the Ni coating layer of the raised portion is preferably 0.1 μm or more.

[0048]

In this embodiment, the film thickness of the Ni coating layer of the flat portion of the hot-dipped checkered steel plate is preferably 0.05 μm or more per surface on average when viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other. In a case where the film thickness is less than 0.05 μm , unplating occurs at the flat portion. The upper limit of the film thickness of the Ni coating layer of the flat portion is 0.35 μm or less per surface on average. In a case where the film thickness is more than 0.35 μm , the plating adhesion improving effect at the flat portion is saturated, and there is no economic advantage.

[0049]

In this embodiment, the film thickness of the Ni coating layer of the raised portion is required to be more than 100% and 400% or less of the film thickness of the Ni coating layer of the flat portion when viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other.

[0050]

As described above, in the checkered steel plate, Ni is adhered to a raised portion in preference to a flat portion under conventional electro plating conditions. For example, the inventors have confirmed that in a case where the distance between electrodes between the raised portion of the checkered steel plate and the anode is less than 40 mm as in the related art, the film thickness of the Ni coating layer of the raised portion may be 2,000% or more of the film thickness of the Ni coating layer of the flat

portion.

[0051]

However, as described above, the present inventors have found that it is necessary to make the film thickness of the Ni coating layer of the raised portion not too large in order to improve the corrosion resistance of the raised portion after wear, and it is necessary to secure the film thickness of the Ni coating layer of the flat portion to some extent in order to suppress unplating at the flat portion. That is, in this embodiment, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised portion $\div$ film thickness of flat portion $\times 100$) is made smaller than that of a hot-dipped checkered steel plate of the related art.

[0052]

In a case where the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised portion $\div$ film thickness of flat portion $\times 100$) is more than 400%, it is difficult to preferably achieve both suppression of unplating at the flat portion and corrosion resistance after wear at the raised portion. Accordingly, in this embodiment, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion is controlled to be 400% or less. The ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion is preferably 350% or less, more preferably 300% or less, and most preferably 250% or less.

[0053]

On the other hand, in electro plating, it is substantially difficult that the film thickness of the Ni coating layer of the raised portion is smaller than the film thickness

of the Ni coating layer of the flat portion, or the film thickness of the Ni coating layer of the raised portion and the film thickness of the Ni coating layer of the flat portion are the same due to the shape of the checkered steel plate. Therefore, in this embodiment, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion is controlled to be more than 100%.

[0054]

By controlling the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion within the above range, it is possible to obtain an effect of achieving both suppression of unplating at the flat portion and corrosion resistance after wear at the raised portion. In addition, it is possible to reduce the adhesion amount of Ni of an unnecessary region (raised portion) by increasing the adhesion amount of Ni of a necessary region (flat portion). Accordingly, Ni, which is a finite resource, can be effectively used.

[0055]

Next, the base steel plate of the hot-dipped checkered steel plate according to this embodiment will be described in detail.

[0056]

In this embodiment, the base steel plate (a plate to be plated) is a checkered steel plate. Usually, a raised portion shape is imparted to the checkered steel plate by hot rolling. The kind of steel of the base steel plate is not particularly limited, and usually, a kind of steel corresponding to a general structural rolled steel specified in JIS G3101 is used. For example, the raised portion shape of the checkered steel plate can be imparted by transferring a recessed shape formed on the operating roll to the surface of the steel plate during the finish stage of the hot rolling. In this embodiment, the

checker pattern height (raised portion height) and the occupation ratio of the checkered portion (raised portion portion) are not necessarily limited. However, particularly, from the viewpoint of usability and slip prevention of the steel plate as a floorboard, the checker pattern height is controlled to be 0.5 to 3.5 mm, and the occupation ratio of the checkered portion is controlled to be 15% to 60%.

[0057]

FIGS. 1A to 1C show a shape of the checkered steel plate serving as a base steel plate. FIG. 1A is a schematic view when a base steel plate of a hot-dipped checkered steel plate according to an embodiment of the present invention is viewed from a thickness direction. FIG. 1B is a cross-sectional view taken along line G-G of FIG. 1A, which is a schematic cross-sectional view when the base steel plate of the hot-dipped checkered steel plate according to the embodiment is viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other. FIG. 1C is a cross-sectional view taken along line F-F of FIG. 1A, which is a schematic cross-sectional view when the base steel plate of the hot-dipped checkered steel plate according to the embodiment is viewed in a cut surface where the thickness direction and the cutting direction are parallel to each other. A, B, C, D, E, and H in these drawings are as follows, respectively: A: Arrangement angle of raised portions with respect to rolling direction; B: Length of one raised portion; C: Maximum width of one raised portion; D: Minimum width of one raised portion; E: Arrangement pitch of raised portions; and H: Raised portion height

[0058]

Next, an observation method and a measurement method for the hot-dipped checkered steel plate according to this embodiment will be described.

[0059]

Regarding the raised portion and the flat portion of the hot-dipped checkered steel plate, the appearance and the cross section of the hot-dipped checkered steel plate may be observed. For example, in a case where a hot-dipped checkered steel plate has the same appearance as the checkered steel plate shown in FIG. 1A when observed from a thickness direction, it can be judged that a raised portion and a flat portion exist in the hot-dipped checkered steel plate.

[0060]

More specifically, whether the raised portion and the flat portion exist may be judged by observing the hot-dipped checkered steel plate in a cross section corresponding to the cross section taken along line G-G of FIG. 1A, that is, a cut surface including a center point (center of gravity) of the raised portion and a long axis of the raised portion, where a cutting direction is parallel to a thickness direction. For example, with respect to the contour curve of the hot-dipped checkered steel plate appearing in the cross section, a reference line is determined based on a region corresponding to the flat portion of the hot-dipped checkered steel plate, and the distance between the reference line and the apex of the highest mountain on the contour curve is obtained. In a case where the distance is 0.5 mm or more, the mountain on the contour curve may be judged as a raised portion. In a case where the number of the raised portions is one or more per 100 mm² when the steel plate is observed from the thickness direction, it may be judged that the steel plate is a hot-dipped checkered steel plate.

[0061]

Whether the hot-dipped checkered steel plate has the base steel plate, the Ni coating layer, and the hot-dip coating layer may be observed by a field emission scanning electron microscope (FE-SEM) or a transmission electron microscope (TEM).

For example, a test piece may be cut out such that the cutting direction is parallel to the thickness direction, and a cross section structure of the cut surface may be observed by an FE-SEM or a TEM at such a magnification that the respective layers are in the observed visual field. FIG. 2 shows a schematic view of a cross section structure of the hot-dipped checkered steel plate according to this embodiment.

[0062]

For example, in the identification of the respective layers in the cross section structure, line analysis may be performed using energy dispersive X-ray spectroscopy (EDS) along the thickness direction at a magnification of 20,000 times with an accelerating voltage of 15 kV, an irradiation current of 10 nA, a beam diameter of about 100 nm (weak), a measurement pitch of 0.025 μm , and an aperture diameter of an objective lens of 30 $\mu\text{m}\phi$ to perform quantitative analysis of the chemical compositions of the respective layers with a total content of Ni, Fe, and Zn of up to 100 mass%. In order to remove measurement noise, a moving average process may be performed on the results of the line analysis to average the data at five fore-and-aft points, and then a region where the Ni concentration is 50 mass% or more on the scanning line may be judged as the Ni coating layer. In addition, based on the Ni coating layer identified on the scanning line, a region on the surface side may be judged as the hot-dip coating layer, and a region on the inner side may be judged as the base steel plate. The hot-dip coating layer is a Zn-based alloy, and the base steel plate is a Fe-based alloy.

[0063]

The film thickness of the Ni coating layer of the raised portion may be measured by identifying the Ni coating layer of the raised portion in a cross section corresponding to the cross section taken along line G-G of FIG. 1A and by measuring

the film thickness of the Ni coating layer. For example, in the cross section, line analysis may be performed along the thickness direction such that the apex of the highest mountain on the contour curve of the hot-dipped checkered steel plate is included, the Ni coating layer may be identified on the scanning line of the line analysis, the line segment of the Ni coating layer on the scanning line may be obtained, and the line segment may be employed as a film thickness of the Ni coating layer of the raised portion.

[0064]

The film thickness of the Ni coating layer of the flat portion may be measured in the same manner as described above. For example, in a cross section corresponding to the cross section taken along line G-G of FIG. 1A, line analysis may be performed along the thickness direction on the flat portion at a position separated by 2 mm or more from an end portion of the raised portion, the Ni coating layer may be identified on the scanning line of the line analysis, the line segment of the Ni coating layer on the scanning line may be obtained, and the line segment may be employed as a film thickness of the Ni coating layer of the flat portion.

[0065]

As the film thickness of the Ni coating layer of each of the raised portion and the flat portion, an average of values measured at at least three portions may be employed. In a case where the film thickness of the Ni coating layer of each of the raised portion and the flat portion is less than 0.3 μm , the film thickness is preferably obtained by TEM instead of SEM.

[0066]

The ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised

portion ÷ film thickness of flat portion×100) may be calculated based on the film thicknesses of the Ni coating layers of the raised portion and the flat portion obtained as above.

[0067]

The chemical composition and the adhesion amount of the hot-dip coating layer may be measured using inductively coupled plasma (ICP: Inductive Coupled Plasma) emission spectroscopic analysis. For example, a sample having a size of 30 mm × 30 mm may be collected from any portion of the hot-dipped checkered steel plate, only the coating layer may be pickled and peeled from the sample using a 10% hydrochloric acid containing an inhibitor (for example, IBIT manufactured by Asahi Chemical Co., Ltd., model number: IBIT 710-K, concentration: 300 ppm, ppm is mg/kg) added thereto, concentrations of the respective elements may be obtained by performing ICP quantitative analysis, and the chemical composition and the adhesion amount of the hot-dip coating layer may be obtained from the concentrations of the respective elements. The above measurement may be performed on samples collected from at least three or more portions, and an average of values measured may be employed.

[0068]

The coverage of the hot-dip coating layer with respect to the surface of the base steel plate may be obtained by observing the hot-dipped checkered steel plate from the thickness direction. For example, a sample of 100 mm × 100 mm may be collected from any portion of the hot-dipped checkered steel plate, and observed from the thickness direction to obtain an area ratio of an unplated region in the area of the sample. The area ratio may be obtained using image analysis software (for example, WinROOF manufactured by Mitani Corporation). More specifically, the sample of

100 mm × 100 mm may be divided into such a size that the measurement by EDS or electron probe micro-analyzer (EPMA) is possible, the divided samples may be subjected to surface analysis using EDS or EPMA to obtain a Fe distribution map, and the area ratio of the unplated region (a region where the Fe concentration is 20 mass% or more) in the area of the sample may be obtained from the Fe distribution map. The coverage of the hot-dip coating layer may be obtained based on the area ratio of the unplated region.

[0069]

Next, a manufacturing method of the hot-dipped checkered steel plate according to this embodiment will be described in detail.

[0070]

The manufacturing method of the hot-dipped checkered steel plate according to this embodiment includes a rolling step of providing a raised portion and a flat portion on a rolled surface of the steel plate, a pre-plating step of performing Ni pre-plating on the steel plate subjected to the rolling step, and a hot-dip coating step of performing hot-dip coating on the steel plate subjected to the pre-plating step. In the pre-plating step, electro Ni plating is performed under conditions in which the rolled surface of the steel plate and the anode surface are disposed to be opposed to each other, the distance between electrodes between the raised portion of the rolled surface and the anode is controlled to be 40 to 100 mm, and the adhesion amount of plating per surface is 0.5 to 3 g/m² on average. In the hot-dip coating step, the steel plate is heated, dipped in a hot-dip coating bath containing, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities, and subjected to continuous hot-dip coating under conditions in which the adhesion amount of plating per surface is 60 to

400 g/m² on average.

[0071]

In the rolling step, a raised portion and a flat portion are provided on a rolled surface of the steel plate. The rolling conditions are not particularly limited, and a raised portion and a flat portion may be provided on the rolled surface of the steel plate by transferring a recessed shape formed on the operating roll to the surface of the steel plate during the finish stage of the hot rolling. The checkered steel plate shaped by hot rolling is subjected to a pre-treatment such as pickling to remove scale and the like. The surface of the steel plate may be optionally subjected to brush grinding or the like.

[0072]

In the pre-plating step, Ni pre-plating is performed on the pre-treated checkered steel plate. As Ni pre-plating, it is desirable to use electro plating from the viewpoint of productivity and suppression of mixing of impurity elements. Examples of the electro plating include a method using a watt bath or a sulfamic acid bath.

[0073]

In the method using a watt bath, the composition of the Ni coating bath preferably includes NiSO₄·6H₂O: 250 to 350 g/L, Na₂SO₄: 50 to 150 g/L, and H₃BO₃: 30 to 50 g/L with a pH of 2 to 3.5, the bath temperature is preferably 50°C to 70°C, and the cathode current density is preferably 5 to 30 A/dm². Specifically, for example, the conditions are as follows: NiSO₄·6H₂O: 340 g/L; Na₂SO₄: 100 g/L; H₃BO₃: 45 g/L; pH: 2.5; temperature: 60°C; and cathode current density: 20 A/dm².

[0074]

In this embodiment, the adhesion amount of Ni in the Ni pre-plating is increased compared to the method of the related art in order to prevent the occurrence of unplating in the hot-dip coating step. However, excessive precipitation of Ni at the

raised portion is avoided such that corrosion of the steel sheet is suppressed even in a case where the hot-dip coating layer is worn and the Ni coating layer is exposed at the raised portion.

[0075]

Usually, in an electro plating cell (electrolytic cell), a steel strip is used as a cathode, and an anode is disposed to be opposed to the surface of the steel plate. A surface of the steel strip and the anode are parallel to each other and approximated by a parallel plate electrode system. In a case where electro plating is performed on a checkered steel plate in such an electrolytic cell, the distance between electrodes between the raised portion of the checkered steel plate and the anode is short. Accordingly, a current is likely to be concentrated at the raised portion. In this embodiment, the distance between electrodes (the distance between the raised portion of the surface of the steel strip and the anode) is increased to suppress the current concentration at the raised portion of the checkered steel plate. Under the conventional conditions, the distance between electrodes is set to be less than 40 mm in order to suppress the power cost while securing uniformity of the current distribution. In this embodiment, however, the distance between electrodes is set to 40 to 100 mm. In a case where the distance between electrodes is less than 40 mm, current concentration occurs at the raised portion, and it is difficult to control the thickness of the Ni coating layer of the raised portion within a predetermined range. In a case where the distance between electrodes is more than 100 mm, electric power loss due to the liquid resistance is increased. The lower limit of the distance between electrodes is preferably 45 mm, and more preferably 50 mm. The upper limit of the distance between electrodes is preferably 90 mm, and more preferably 85 mm.

[0076]

For example, in a hot-dipped checkered steel plate manufactured after setting the distance between electrodes to be less than 40 mm as in the related art, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised portion ÷ film thickness of flat portion×100) may be 2,000% or more. In contrast, in a hot-dipped checkered steel plate manufactured after setting the distance between electrodes to 40 mm or more, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion is easily controlled to 400% or less. In a case where the distance between electrodes is set to 45 mm or more, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion is easily controlled to 300% or less in the manufacturing of the hot-dipped checkered steel plate.

[0077]

In the pre-plating step, the average adhesion amount of Ni pre-plating per surface is controlled to be 0.5 to 3 g/m². In a case where the average adhesion amount is less than 0.5 g/m², the film thickness of the Ni coating layer of the flat portion of the checkered steel plate after hot-dip coating is less than 0.05 μm, and unplating is likely to occur. In a case where the average adhesion amount is more than 3 g/m², the amount of the Ni coating layer remaining at the raised portion after hot-dip coating is excessive, and it is difficult to control the thickness of the Ni coating layer at the raised portion to 0.4 μm or less.

[0078]

The adhesion amount of Ni in the Ni pre-plating may be measured based on the following steps a to e before the hot-dip coating of the Zn-based alloy.

Step a: A steel plate subjected to Ni pre-plating is dissolved with a 30 mass%

nitric acid (solution A).

Step b: A sample is collected from the vicinity of the sample used in Step a. After removal of the Ni pre-coating layer by grinding or the like, the sample is dissolved with a 30 mass% nitric acid (solution B).

Step c: The amount of Fe and the amount of Ni dissolved in the solution B is obtained by ICP, and a ratio between the amount of Fe and the amount of Ni is obtained.

Step d: The amount of Fe dissolved in the solution A is obtained by ICP, and the amount of Ni dissolved from the base steel plate is obtained from the ratio calculated in Step c.

Step e: The amount of Ni dissolved in the solution A is obtained by ICP, and the amount of Ni derived from the base steel plate calculated in Step d is subtracted therefrom to calculate the amount of Ni derived from the Ni pre-coating layer. The amount of Ni derived from the Ni pre-coating layer is converted to the adhesion amount per unit area.

[0079]

Edge overcoating may occur due to current concentration at an end portion of the steel plate in the width direction in continuous electro plating equipment for a steel strip, although also depending on the design of the electrolytic cell. Therefore, in the calculation of the average adhesion amount, the end portion of the steel strip in the width direction (for example, a region of 50 mm from both ends) may be excluded from the measurement target.

[0080]

In the hot-dip coating step, the checkered steel plate (steel strip) subjected to Ni pre-plating is pre-heated in a non-oxidizing atmosphere, and then continuously

passes through a hot-dip coating cell (continuously dipped in a hot-dip coating bath). The non-oxidizing atmosphere is, for example, a mixed gas of nitrogen and hydrogen. The preheating temperature is preferably within a range of [temperature of coating bath + 10°C] to [temperature of coating bath + 50°C]. In a case where the preheating temperature is low, unplating is likely to occur frequently. In the pre-heating, the checkered steel plate is preferably rapidly heated such that the period of time during which the temperature of the steel plate is 350°C or higher is 40 seconds or less. By shortening the period of time during which the temperature of the steel plate is 350°C or higher, it is possible to suppress diffusion of Ni to the base steel plate, and thus it is possible to secure a sufficient Ni pre-plating amount for preventing unplating.

[0081]

The checkered steel plate pre-heated in a non-oxidizing atmosphere passes through a coating bath of a hot-dip zinc-based alloy containing Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, and optionally, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% (is dipped in the hot-dip coating bath). The temperature of the coating bath is preferably within a range of [melting point of molten Zn-based alloy + 20°C] to [melting point of molten Zn-based alloy + 50°C]. The checkered steel plate is preferably dipped in the coating bath for 1 to 6 seconds, and then wiped. The checkered steel plate is optionally cooled by air-water spray or the like.

[0082]

In the hot-dip coating step, the average adhesion amount of the hot-dip coating layer per surface is controlled to be 60 to 400 g/m². In a case where the average adhesion amount is less than 60 g/m², the corrosion resistance may be insufficient. In a case where the average adhesion amount is more than 400 g/m², the hot-dip coating layer is adhered in an excessive amount. Accordingly, dripping of the

plating may become severe and the appearance may be impaired.

[0083]

The chemical composition of the hot-dip coating bath and the adhesion amount of hot-dip coating may be measured using ICP emission spectroscopic analysis in the same manner as described above. The chemical composition of the hot-dip coating bath may be measured by ICP based on a sample collected from the hot-dip coating bath instead of a sample collected from the hot-dipped checkered steel plate.

[Example 1]

[0084]

Next, the effects of an aspect of the present invention will be described in more detail with examples. The conditions in the examples are merely one condition example employed to confirm the operability and effects of the present invention, and the present invention is not limited to the one condition example. The present invention can employ various conditions as long as the object of the present invention is achieved without departing from the gist of the present invention.

[0085]

A hot-rolled checkered steel plate having a thickness of 2.3 mm was used as a base plate to be plated.

The shape of the checkered steel plate (base steel plate) was the same as in FIGS. 1A to 1C. A, B, C, D, E, and H in these drawings are as follows, respectively:

A: Arrangement angle of raised portions with respect to rolling direction;

B: Length of one raised portion;

C: Maximum width of one raised portion;

D: Minimum width of one raised portion;

E: Arrangement pitch of raised portions; and

H: Raised portion height

The checkered steel plate was a hot-rolled Al-killed steel, having an angle $A = 45^\circ$, a width $C = 5.1$ mm, a length $B = 25.3$ mm, a height $H = 1.5$ mm, and a pitch $E = 28.6$ mm. The checkered steel plate having raised portions arranged regularly was pickled and subjected to Ni pre-plating with various distance between electrodes to change the average adhesion amount of Ni. Tables 1 and 2 show the conditions for Ni pre-plating. The electrolysis efficiency was about 80%. The obtained checkered steel plate had a cross section structure as shown in FIG. 2.

[0086]

[Table 1]

Composition of Coating Bath	NiSO ₄ ·6H ₂ O: 340 g/L Na ₂ SO ₄ : 100 g/L H ₃ BO ₃ : 45 g/L pH: 2.5
Bath Temperature	60°C
Electrolysis Conditions	Cathode Current Density: 20 A/dm ² (insoluble anode)

[0087]

The steel plate subjected to Ni pre-plating was subjected to hot-dip coating of a Zn-based alloy using a hot-dip coating bath of the Zn-based alloy shown in Table 2. Table 2 also shows the temperature of the hot-dip coating bath of the Zn-based alloy. In hot-dip coating of the Zn-based alloy, the steel plate was heated to (temperature of coating bath of Zn-based alloy + 30°C) at a rate of temperature increase of 10°C/sec in a non-oxidizing atmosphere (N₂-2% H₂), and cooled to (temperature of coating bath + 10°C) in the above atmosphere. Then, the steel plate was dipped in the coating bath. The dipping time was 3 seconds, and the adhesion amount of hot-dip coating was adjusted by a hot-dip coating adhesion amount adjuster on the outlet side of the hot-dip coating device.

[0088]

[Table 2]

	Manufacturing Conditions								
	Ni Pre-Plating Step		Hot-dip coating step						
	Adhesion Amount [g/m ²]	Distance between electrodes [mm]	Chemical Composition of Hot-Dip Coating Bath [mass%]						Bath Temperature [°C]
			Zn	Al	Mg	Sn	Ca	Si	
Example 1	2	45	85.4	11	3.4	-	-	0.2	460
Example 2	0.8	45	85.4	11	3.4	-	-	0.2	460
Example 3	3	45	85.4	11	3.4	-	-	0.2	460
Example 4	2	40	85.4	11	3.4	-	-	0.2	460
Example 5	2	90	85.4	11	3.4	-	-	0.2	460
Example 6	2	45	98.75	1.2	0.05	-	-	<0.004	440
Example 7	2	45	91.8	6	2.1	-	-	0.1	440
Example 8	2	45	80	15	4.1	0.5	-	0.4	470
Example 9	2	45	71.5	20	6	2	0.3	0.2	490
Example 10	2	45	66.5	25	8	-	0.5	<0.004	520
Comparative Example 1	2	25	85.4	11	3.4	-	-	0.2	460
Comparative Example 2	0.3	45	85.4	11	3.4	-	-	0.2	460
Comparative Example 3	3.5	45	85.4	11	3.4	-	-	0.2	460
Comparative Example 4	2	45	99.2	0.7	0.1	-	-	<0.004	440
Comparative Example 5	2	45	68.4	28	3.5	-	-	0.1	540
Comparative Example 6	2	45	88.87	11	0.03	-	-	0.1	460
Comparative Example 7	2	45	76.9	11	12	-	-	0.1	490
Comparative Example 8	2	45	85.4	11	3.4	-	-	0.2	490

[0089]

Based on the above-described observation and measurement methods, whether the obtained hot-dipped checkered steel plate had the base steel plate, the Ni coating layer, and the hot-dip coating layer in a cross section structure thereof, and whether the surface of the base steel plate had a raised portion and a flat portion were confirmed. In addition, the film thickness of the Ni coating layer of the raised portion, the film thickness of the Ni coating layer of the flat portion, the ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised portion ÷ film thickness of flat portion×100), the adhesion amount of the hot-dip coating layer, the chemical composition of the hot-dip coating layer, the coverage of the hot-dip coating layer, the adhesion amount of Ni in the Ni pre-plating, the chemical composition of the hot-dip coating bath, and the like were measured.

[0090]

In addition, the obtained hot-dipped checkered steel plate was evaluated based

on the following method.

[0091]

Corrosion Test After Wear

A steel plate having a 5 mm-thick styrene-butadiene rubber stuck thereto was placed on a sample of 100 mm × 50 mm, and a 1 kg weight was placed thereon to give a reciprocating vibration (stroke: 30 mm, reciprocation frequency: 1,000 times) in a lateral direction, thereby wearing the plating. The worn steel plate was exposed southward on the exposure stand at an inclination of 45° to the ground, and a test was continued for one month in which 20 ml of a 5% NaCl aqueous solution was sprayed once a week in an environment exposed to rain. After the test was continued for one month, the area ratio of red rust generated in the vicinity of the raised portion was evaluated. For the evaluation of the area ratio of red rust generated, WinROOF (image analysis software) manufactured by Mitani Corporation was used. The area of the portion where the red rust was generated was measured, and the area ratio was calculated. The area ratio of the portion where the red rust was generated was measured by extracting the color of red rust by color extraction. In a case where the area ratio of red rust generated was 5% or more, the corrosion resistance after wear was determined to be poor. In the table, a case of area ratio of red rust generated: less than 5% is expressed by “Good”, and a case of area ratio of red rust generated: 5% or more is expressed by “Bad”.

[0092]

Plating Appearance

A 100 mm square sample was prepared, and a plating surface was observed from a thickness direction. The area ratio of a region where the plating appearance was deteriorated due to dross (called “dross area ratio”) was measured using

WinROOF (image analysis software) manufactured by Mitani Corporation. In a case where the area ratio of dross was 20% or more, the plating appearance was determined to be poor. In the table, a case of area ratio of dross: less than 20% is expressed by “Good”, and a case of area ratio of dross: 20% or more is expressed by “Bad”.

[0093]

Workability

A sample was V-bent 90°, and then a polyester adhesive tape manufactured by NITTO DENKO CORPORATION was attached to the outside of the bent portion, and peeled therefrom. Then, it was confirmed whether a peeled material from the coating layer had adhered to the tape. In a case where the peeled material from the coating layer adhered to the tape, the workability was determined to be poor. In the table, a case where there is no peeled material is expressed by “Good”, and a case where there is a peeled material is expressed by “Bad”.

[0094]

Table 3 shows the manufacturing results and the evaluation results of the manufactured hot-dipped checkered steel plates. “Film Thickness Ratio of Ni Coating Layer” shown in Table 3 means a ratio of the film thickness of the Ni coating layer of the raised portion to the film thickness of the Ni coating layer of the flat portion (film thickness of raised portion ÷ film thickness of flat portion×100).

[0095]

[Table 3]

	Manufacturing Results											Evaluation Results							Remarks		
	Hot-Dip Coating Layer											Ni Coating Layer									
	Chemical Composition [mass%]											Adhesion Amount [g/m ²]	Flat Portion [μm]		Raised portion [μm]	Film Thickness Ratio [%]	Coverage of Hot-dip coating [%]	Corrosion Resistance After Wear		Plating Appearance	Workability
	Zn	Al	Mg	Ni	Fe	Sn	Ca	Si													
Example 1	85.66	10.4	3.65	0.18	<0.004	-	-	0.1				272	0.14	0.27	193	99.9	Good	Good			
Example 2	85.66	10.4	3.65	0.06	<0.004	-	-	0.1				70	0.05	0.12	240	99.2	Good	Good			
Example 3	85.66	10.4	3.65	0.24	<0.004	-	-	0.1				252	0.19	0.36	189	99.9	Good	Good			
Example 4	85.66	10.4	3.65	0.18	<0.004	-	-	0.1				260	0.1	0.35	350	99.5	Good	Good			
Example 5	85.66	10.4	3.65	0.18	<0.004	-	-	0.1				220	0.18	0.2	111	99.6	Good	Good			
Example 6	98.25	1.5	0.05	0.2	<0.004	-	-	<0.004	-			302	0.13	0.27	208	99.6	Good	Good			
Example 7	91.78	6	2	0.22	<0.004	-	-	0.1			306	0.14	0.3	214	99.6	Good	Good				
Example 8	80.74	15	4	0.26	<0.004	0.5	-	0.4			220	0.15	0.29	193	99.4	Good	Good				
Example 9	73.8	20	6	0.2	<0.004	2	0.3	0.2			250	0.13	0.28	215	99.6	Good	Good				
Example 10	66.84	25	8	0.16	<0.004	-	0.5	<0.004			181	0.14	0.27	193	99.3	Good	Good				
Comparative Example 1	85.66	10.4	3.65	0.18	<0.004	-	-	0.1			220	0.02	0.45	2250	89.5	Bad	Good				
Comparative Example 2	85.66	10.4	3.65	0.18	<0.004	-	-	0.1			270	0	0.04	-	80	Bad	Good				
Comparative Example 3	85.66	10.4	3.65	0.18	<0.004	-	-	0.1			265	0.25	0.45	180	99.8	Bad	Good				
Comparative Example 4	98.94	0.8	0.1	0.15	0.01	-	-	<0.004			324	0.15	0.29	193	99.4	Bad	Good				
Comparative Example 5	68.18	28	3.65	0.17	<0.004	-	-	0.1			165	0.14	0.27	193	99.2	Good	Bad				
Comparative Example 6	89.37	10.4	0.03	0.2	<0.004	-	-	0.1			193	0.13	0.28	215	99.5	Bad	Good				
Comparative Example 7	77.39	10.4	12	0.21	<0.004	-	-	0.1			175	0.14	0.28	200	99.4	Good	Good				
Comparative Example 8	85.66	10.4	3.65	0.18	<0.004	-	-	0.1			50	0.13	0.27	208	99.4	Bad	Good				

[0096]

In Comparative Example 1, since the distance between electrodes was not appropriate in Ni pre-plating, the film thickness of the Ni coating layer of the raised portion was more than 0.4 μm , and the film thickness of the Ni coating layer of the flat portion was less than 0.05 μm . As a result, plating defects were caused due to unplating, and it was not possible to obtain sufficient corrosion resistance in the corrosion test after wear.

In Comparative Example 2, since the adhesion amount of Ni pre-plating was small, the film thickness of the Ni coating layer of the flat portion of the checkered steel plate was not sufficient. As a result, plating defects were caused due to unplating, and it was not possible to obtain sufficient corrosion resistance.

In Comparative Example 3, since the adhesion amount of Ni pre-plating was large, the film thickness of the Ni coating layer of the raised portion was more than 0.4 μm . As a result, it was not possible to obtain sufficient corrosion resistance in the corrosion test after wear.

In Comparative Example 4, since the amount of Al in the hot-dip coating layer of the Zn-based alloy was small, it was not possible to obtain sufficient corrosion resistance, and the plating appearance was poor.

In Comparative Example 5, since the amount of Al in the hot-dip coating layer of the Zn-based alloy was large, the plating appearance was poor, the workability was not sufficient, and the hot-dipped checkered steel plate was not industrially preferable.

In Comparative Example 6, since the amount of Mg in the hot-dip coating layer of the Zn-based alloy was small, it was not possible to obtain sufficient corrosion resistance.

In Comparative Example 7, since the amount of Mg in the hot-dip coating

layer of the Zn-based alloy was large, the plating appearance was poor, and the hot-dipped checkered steel plate was not industrially preferable.

In Comparative Example 8, since the adhesion amount of the hot-dip coating layer of the Zn-based alloy was small, it was not possible to obtain sufficient corrosion resistance.

In contrast, in Examples 1 to 10, the occurrence of unplating was suppressed, and sufficient corrosion resistance was obtained even after wear. In addition, plating appearance and workability were also satisfied.

[Industrial Applicability]

[0097]

According to the aspect of the present invention, it is possible to provide a hot-dipped checkered steel plate in which the occurrence of unplating is suppressed, and corrosion occurring in a case where a hot-dip coating layer is worn and a Ni coating layer is exposed is also suppressed, and a manufacturing method of the hot-dipped checkered steel plate. Therefore, the present invention has high industrial applicability.

[Brief Description of the Reference Symbols]

[0098]

1: raised portion

2: flat portion

3: hot-dip coating layer of Zn-based alloy

4: Ni coating layer

5: base steel plate

[Document Type] CLAIMS

What is claimed is:

1. A hot-dipped checkered steel plate comprising:
 - a base steel plate;
 - a Ni coating layer which is disposed on a surface of the base steel plate; and
 - a hot-dip coating layer which is disposed on a surface of the Ni coating layer,wherein a raised portion and a flat portion are provided on the surface of the base steel plate,
 - a film thickness of the Ni coating layer of the raised portion is 0.07 to 0.4 μm per surface,
 - a film thickness of the Ni coating layer of the flat portion is 0.05 to 0.35 μm per surface,
 - the film thickness of the Ni coating layer of the raised portion is more than 100% and 400% or less of the film thickness of the Ni coating layer of the flat portion,
 - an adhesion amount of the hot-dip coating layer is 60 to 400 g/m^2 per surface,and
 - the hot-dip coating layer contains, as a chemical composition, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities.
2. The hot-dipped checkered steel plate according to claim 1,
 - wherein the film thickness of the Ni coating layer of the raised portion is more than 100% and 300% or less of the film thickness of the Ni coating layer of the flat portion.

3. The hot-dipped checkered steel plate according to claim 1 or 2,
wherein the film thickness of the Ni coating layer of the raised portion is 0.07 to 0.3 μm per surface.

4. The hot-dipped checkered steel plate according to any one of claims 1 to 3,
wherein the hot-dip coating layer contains, as a chemical composition, by mass%, Al: 4.0% to 25.0% and Mg: 1.5% to 8.0%.

5. The hot-dipped checkered steel plate according to any one of claims 1 to 4,
wherein the hot-dip coating layer contains, as a chemical composition, by mass%, at least one selected from the group consisting of Si: 0.05% to 1.0%, Sn: 0.1% to 3.0%, or Ca: 0.01% to 1.0%.

6. The hot-dipped checkered steel plate according to any one of claims 1 to 5,
wherein a coverage of the hot-dip coating layer is 99% to 100% by area% with respect to the surface of the base steel plate when viewed from a thickness direction.

7. A manufacturing method of the hot-dipped checkered steel plate according to any one of claims 1 to 6, comprising:
a rolling step of providing a raised portion and a flat portion on a rolled surface of the steel plate;

a pre-plating step of performing Ni pre-plating on the steel plate subjected to the rolling step; and

a hot-dip coating step of performing hot-dip coating on the steel plate subjected to the pre-plating step,

wherein in the pre-plating step, electro Ni plating is performed under conditions in which the rolled surface of the steel plate and an anode surface are disposed to be opposed to each other, a distance between electrodes between the raised portion of the rolled surface and the anode is controlled to be 40 to 100 mm, and an adhesion amount of plating per surface is 0.5 to 3 g/m² on average, and

in the hot-dip coating step, the steel plate is heated, dipped in a hot-dip coating bath containing, by mass%, Al: more than 1.0% and 26% or less, Mg: 0.05% to 10%, Si: 0% to 1.0%, Sn: 0% to 3.0%, and Ca: 0% to 1.0% with a remainder consisting of Zn and impurities, and subjected to continuous hot-dip coating under conditions in which an adhesion amount of plating per surface is 60 to 400 g/m² on average.

8. The manufacturing method of the hot-dipped checkered steel plate according to claim 7,

wherein in the pre-plating step, the distance between electrodes is controlled to be 45 to 100 mm.