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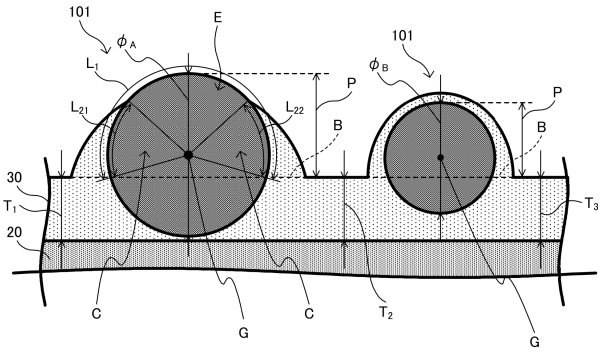
(54) COATED STEEL SHEET

(57) [PROBLEM] To provide a painted steel sheet which can be further improved in corrosion resistance and productivity while having a low-gloss paint film layer having a particle or a thin film portion.

[SOLUTION] Provided is a painted steel sheet including two or more paint film layers including a rust preventive paint film layer on at least one side of a steel sheet having a Zn-containing plating layer, wherein: a 60-degree specular glossiness Gs (60°) specified in JIS Z 8741:1997 of the paint film layer on at least one face of the steel sheet is 20% or less; an average film thickness of the rust preventive paint film layer is 5 μm or more and 15 μm or less; the rust preventive paint film layer contains a binder resin, a cross-linking agent, and a rust preventive pigment; and in a cross section obtained by cutting the paint film layer in a thickness direction at an arbitrary position, a coverage ratio of the rust preventive pigment to a total area of the rust preventive paint film layer is 30% or more and 60% or less in terms of area ratio.

FIG.2A



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Description

TECHNICAL FIELD

[0001] The present invention relates to a painted steel sheet.

BACKGROUND ART

[0002] Steel sheets with high design are increasingly used for applications for building material use, home appliance use, automobile use, and so on. A steel sheet has a matte appearance with suppressed gloss as an example of the high design. Examples of the steel sheet having the matte appearance include a low-gloss painted steel sheet with an organic coating layer containing resin particles which is provided on a steel sheet surface, and so on. Further, as a steel sheet having a paint film layer on the surface, there is a known steel sheet provided with a rust preventive paint film layer containing a rust preventive pigment for improving the corrosion resistance of the steel sheet.

[0003] For example, Patent Document 1 below proposes a technique of improving, in a zinc-based plated steel sheet having an organic coating, the abrasion resistance of the organic coating by containing a resin particle having a particle diameter larger than the film thickness of the organic coating (hereinafter, also referred to as a "large-diameter particle") in the organic coating.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0004] Patent Document 1: International Publication Pamphlet No. WO 2014/112544

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005] The steel sheet having the matte appearance is subjected to low-gloss painting or the like and thus has large recesses and projections on a steel sheet surface to suppress the reflection of light by the recesses and projections and realize the low gloss. Accordingly, a layer constituting the low-gloss painting (hereinafter, also called a "low-gloss paint film layer") can contain a thin film portion. If a flaw or the like occurs at the thin film portion, a corrosion factor in an environment such as rain water is likely to intrude through the flaw or the like, and can be a factor causing corrosion on the steel sheet surface. Besides, if the organic coating containing the large-diameter particle as proposed in Patent Document 1 above is employed as the low-gloss paint film layer, the large-diameter particle is largely exposed from the binder resin layer constituting the organic coating. The corrosion factor is likely to intrude through the interface between the large-diameter particle and the binder resin layer, and can be a factor causing corrosion on the steel sheet surface.

[0006] Besides, if the zinc-based plated steel sheet having the organic coating containing the large-diameter particle is wound into a coil form or subjected to predetermined press processing, the large-diameter particle falls off the organic coating, resulting in a decrease in design of the organic coating in some cases. Further, the large-diameter particle that has fallen off the organic coating may contaminate various facilities for winding the steel sheet into the coil form or performing the press processing to hinder the processing. From the above, in the case of handling the organic coating containing the large-diameter particle, it is necessary to sufficiently pay attention on handling it and there is room for further improvement from the viewpoint of improving the productivity.

[0007] Hence, the present invention has been made in view of the above problems, and an object of the present invention is to provide a painted steel sheet which can be further improved in corrosion resistance and productivity while having a low-gloss paint film layer having a particle or a thin film portion.

MEANS FOR SOLVING THE PROBLEMS

[0008] As a result of earnest studies for solving the above-described problems, the present inventors obtained the following findings. Specifically, if the surface of a particle having a particle diameter larger than an average film thickness contained in an organic resin coating layer can be covered by an organic resin, the interface between the large-diameter particle and the binder resin layer can be lengthened. Note that owing to the "interface between the large-diameter particle and the binder resin layer is long", a predetermined portion of the particle projecting from the binder resin layer is covered by a film-forming component, so that an exposed portion of the particle can be decreased. Further, lengthening the interface between the large-diameter particle and the binder resin layer as above can suppress the intrusion of the

corrosion factor to suppress the corrosion. Further, it is possible to prevent the fall-off and deformation of the particle. Based on the idea, the present inventors discussed in detail coating conditions of a paint containing the particle having the particle diameter larger than the average film thickness. As a result of this, the present inventors have found that when the average particle diameter of the particle, the average film thickness of the organic resin coating layer, the thickness of the organic resin covering the surface of the particle, and so on satisfy specific conditions, it is possible to prevent the fall-off of the particle from the organic resin coating layer and deformation to further improve the design and the productivity of the painted steel sheet.

[0009] The gist of the present invention completed based on the above findings is as follows.

[1] A painted steel sheet including
two or more paint film layers including a rust preventive paint film layer on at least one side of a steel sheet having a Zn-containing plating layer, wherein:

a 60-degree specular glossiness Gs (60°) specified in JIS Z 8741:1997 of the paint film layer on at least one face of the steel sheet is 20% or less;
an average film thickness of the rust preventive paint film layer is 5 μm or more and 15 μm or less;
the rust preventive paint film layer contains a binder resin, a cross-linking agent, and a rust preventive pigment; and
in a cross section obtained by cutting the paint film layer in a thickness direction at an arbitrary position, a coverage ratio of the rust preventive pigment to a total area of the rust preventive paint film layer is 30% or more and 60% or less in terms of area ratio.

[2] The painted steel sheet according to the above [1], wherein
the rust preventive pigment contains at least one or more of Si, P, Mg, and V.

[3] The painted steel sheet according to the above [2], wherein
the Si contains any one or more of calcium ion-exchanged silica and magnesium ion-exchanged silica, the P contains any one or more of zinc phosphate, magnesium dihydrogen phosphate, and aluminium dihydrogen triphosphate, and the Mg contains any one or more of magnesium dihydrogen phosphate, magnesium oxide, and magnesium hydroxide.

[4] The painted steel sheet according to the above [1] or [2], wherein:

on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, the two or more paint film layers have the rust preventive paint film layer at a lower layer and have a colored paint film layer at an outermost layer located on a farthest side from the steel sheet, and the colored paint film layer contains a resin particle, and a binder resin, a cross-linking agent, and a color pigment as a film-forming component; and
in the cross section, an average particle diameter of the resin particle is two times or more and five times or less an average film thickness at a portion not containing the resin particle of the outermost layer paint film layer.
Where the average particle diameter is a value obtained by measuring, in one observation visual field region in the cross section, circle-equivalent diameters of the resin particles existing in the observation visual field region, calculating an average value of upper two circle-equivalent diameters in descending order of the circle-equivalent diameters, and further averaging the averaged values similarly obtained for the observation visual field regions at ten arbitrary locations, by a number of fields of view.

[5] The painted steel sheet according to the above [4], wherein
the coverage ratio of the resin particles to a total area of the outermost layer paint film layer is 5% or more and 30% or less in terms of area ratio.

[6] The painted steel sheet according to the above [4], wherein
in the cross section, a projecting portion of the resin particle projecting from a position on a surface at the portion not containing the resin particle of the outermost layer paint film layer is covered, at half or more of a length along an outer peripheral portion of the projecting portion, with the film-forming component having a thickness of 0.5 μm or more.

[7] The painted steel sheet according to the above [4], wherein
the resin particle is a resin particle made of an acrylic resin.

[8] The painted steel sheet according to the above [5], wherein
the resin particle is a resin particle made of an acrylic resin.

[9] The painted steel sheet according to the above [6], wherein
the resin particle is a resin particle made of an acrylic resin.

[10] The painted steel sheet according to the above [4], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.

[11] The painted steel sheet according to the above [5], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.
[12] The painted steel sheet according to the above [6], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.
[13] The painted steel sheet according to the above [7], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.
[14] The painted steel sheet according to the above [8], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.
[15] The painted steel sheet according to the above [9], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.
[16] The painted steel sheet according to the above [1] or [2], having a characteristic selected from any one or two of a surface roughness of the steel sheet being 2 μm or more in Ra on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, and the paint film layer containing 15% or more of an aggregate composed of a pigment containing silica.

EFFECT OF THE INVENTION

[0010] As explained above, according to the present invention, it becomes possible to prevent the fall-off of the particle from an organic resin coating layer and deformation to further improve the design and the productivity of a painted steel sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1A is a schematic view for explaining an example of a structure of a painted steel sheet according to an embodiment of the present invention.
FIG. 1B is a schematic view for explaining an example of a structure of a painted steel sheet according to the embodiment.
FIG. 1C is a schematic view for explaining an example of a structure of a painted steel sheet according to the embodiment.
FIG. 2A is a schematic view for explaining an outermost layer paint film layer in the painted steel sheet according to the embodiment.
FIG. 2B is a schematic view for explaining an outermost layer paint film layer in the painted steel sheet according to the embodiment.
FIG. 3A is a schematic view for explaining a thin film part in a painted steel sheet according to another embodiment.
FIG. 3B is a schematic view for explaining a thin film part in a painted steel sheet according to still another embodiment.

EMBODIMENTS FOR CARRYING OUT INVENTION

[0012] Hereinafter, preferred embodiments of the present invention will be explained while referring to the accompanying drawings. Note that in the present description and the drawings, components having substantially the same functional configurations are denoted by the same reference numerals to omit overlapped explanation.

[Regarding a steel sheet 10]

[0013] In a painted steel sheet 1 according to this embodiment, various types of steel sheets can be used as a steel sheet 10 being a base material. It is possible to use various types of steel sheets, as raw materials of the steel sheets, such as Al-killed steel, ultralow carbon steel containing Ti, Nb, and the like, high-strength steel further containing strengthening elements such as P, Si, and Mn in the ultralow carbon steel, and so on.

[0014] It is preferable to use, among the above various types of steel sheets, zinc-based plated steel sheets in which various types of zinc-based plating layers containing at least zinc are provided on surfaces of the steel sheets as substrates, as the steel sheet 10 according to this embodiment. Examples of the zinc-based plated steel sheets include zinc-based plated steel sheets such as a galvanized steel sheet, a zinc-nickel plated steel sheet, a zinc-iron plated steel sheet, a zinc-chromium plated steel sheet, a zinc-aluminum plated steel sheet, a zinc-titanium plated steel sheet, a zinc-magnesium plated steel sheet, a zinc-manganese plated steel sheet, a zinc-aluminum-magnesium plated steel sheet, and a zinc-aluminum-magnesium-silicon plated steel sheet. Further, as the zinc-based plated steel sheet, the ones containing cobalt, molybdenum, tungsten, nickel, titanium, chromium, aluminum, manganese, iron, magnesium, lead, bismuth,

antimony, tin, copper, cadmium, arsenic, and the like as a small amount of dissimilar metal elements or impurities in the plating or the ones in which inorganic substances such as silica, alumina, titania, and the like are dispersed may be used. Further, as the zinc-based plated steel sheet, a steel sheet having multilayer plating made by combining the above plating and other type of plating (for example, iron plating, iron-phosphorus plating, nickel plating, cobalt plating, or the like) may be used. A plating method is not particularly limited and various known plating methods such as an electroplating method, a hot-dip plating method, a vapor deposition plating method, a dispersion plating method, a vacuum plating method, and so on may be used.

[0015] On the surface of the steel sheet 10, a paint film 11 is provided. The paint film 11 includes a rust preventive paint film layer 20. Further, in one embodiment, an outermost layer paint film layer 30 as a colored paint film layer according to this disclosure is included. In the paint film 11, the rust preventive paint film layer 20 is located on the surface of the steel sheet 10. Besides, the outermost layer paint film layer 30 is located at an outermost layer of the paint film 11. The paint film 11 according to this embodiment is provided such that the outermost layer paint film layer 30 is in contact with the surface of the rust preventive paint film layer 20, and another desired coating layer may be provided between the rust preventive paint film layer and the outermost layer paint film layer 30.

[0016] Here, the thickness of the above steel sheet 10 is not particularly limited, and may be appropriately set according to the mechanical strength (for example, tensile strength), workability, or the like required for the painted steel sheet 1 according to this embodiment.

[Regarding the rust preventive paint film layer 20]

[0017] The rust preventive paint film layer 20 provided on the surface of the steel sheet 10 in the painted steel sheet 1 according to this embodiment will be explained. The rust preventive paint film layer 20 is a resin coating layer containing a binder resin, a cross-linking agent, and a rust preventive pigment.

[0018] The rust preventive paint film layer 20 is provided on one side (FIG. 1A) or both sides (FIGS. 1B, C) of the steel sheet 10 as illustrated in FIG. 1A to FIG. 1C. The provision on at least the one side of the steel sheet 10 can suppress the corrosion of the steel sheet 10 on that side. Further, the provision on both sides of the steel sheet 10 can suppress the corrosion of the steel sheet 10 on both sides and exhibit excellent end face corrosion resistance.

[0019] The binder resin contained in the rust preventive paint film layer 20 functions as a film-forming component, and any material can be used. However, from the viewpoints of ease of manufacturing and costs and the viewpoints of corrosion resistance and flaw resistance, it is preferable to use various types of organic resins as the resin. Examples of the resin include an acryl-based resin, a polyester-based resin, a urethane-based resin, a fluorine-based resin, and so on.

[0020] As the rust preventive pigment contained in the rust preventive paint film layer 20, various types of known rust preventive pigments containing a pigment containing at least one or more elements P, V, Si, and Mg can be used.

[0021] Examples of the pigment containing at least one or more elements P, V, Si, and Mg include the Si containing any one of calcium ion-exchanged silica and magnesium ion-exchanged silica, the P containing any one of zinc phosphate, magnesium dihydrogen phosphate, and aluminium dihydrogen triphosphate, the Mg containing any one of magnesium dihydrogen phosphate, magnesium oxide, and magnesium hydroxide, and the V containing calcium vanadate.

[0022] Besides, an average film thickness of the rust preventive paint film layer 20 is 5 μm or more and 15 μm or less. Setting the average film thickness of the rust preventive paint film layer 20 to 5 μm or more can achieve a sufficient effect of suppressing corrosion against a corrosion factor which can intrude through the interface between the thin film portion or particle and the binder resin. The average film thickness of the rust preventive paint film layer 20 is preferably 7.0 μm or more.

[0023] On the other hand, setting the average film thickness of the rust preventive paint film layer 20 to 15 μm or less can suppress the occurrence of a painting defect called popping during the paint baking. The average film thickness of the rust preventive paint film layer 20 is preferably 12 μm or less.

[0024] Further, the rust preventive paint film layer 20 has a coverage ratio of the rust preventive pigment to the total area of the rust preventive paint film layer 20 in observation of a cross section obtained by cutting the paint film 11 in a thickness direction at an arbitrary position is 30% or more and 60% or less in terms of area ratio. Setting the coverage ratio of the rust preventive pigment to 30% or more can achieve a sufficient effect of suppressing corrosion against a corrosion factor which can intrude through the interface between the thin film portion or particle and the binder resin. The coverage ratio of the rust preventive pigment is preferably 40% or more.

[0025] On the other hand, setting the coverage ratio of the rust preventive pigment to 60% or less can achieve sufficient adhesiveness between the rust preventive paint film layer 20 and the steel sheet 10, particularly, the adhesiveness at a worked portion. The coverage ratio of the rust preventive pigment is preferably 50% or less.

[0026] The average film thickness of the rust preventive paint film layer 20 can be specified by the following procedure. First, a cross section obtained by cutting the paint film 11 according to this embodiment in a thickness direction at an arbitrary position is focused on. Then, the cross section is observed under an electron microscope (more specifically, a field emission scanning electron microscope: FE-SEM). Next, the thickness of the rust preventive paint film layer 20 is

measured at ten locations in a field of view in the focused cross section. In this event, the thickness of the rust preventive paint film layer 20 only needs to be measured using a length measurement function or the like installed in the FE-SEM. Then, an average value of obtained measured values at the ten locations is calculated, and regarded as an average value of the thicknesses of the rust preventive paint film layer 20 in the focused field of view. The above operation is performed for the fields of view at ten arbitrary locations, and average values obtained respectively from the fields of view are further averaged by the number of fields of view. The value obtained as above is regarded as an average film thickness of the rust preventive paint film layer 20.

[0027] Besides, the coverage ratio of the rust preventive pigment to the total area of the rust preventive paint film layer 20 is calculated as follows. Specifically, the cross section obtained by cutting the paint film 11 according to this embodiment in the thickness direction at the arbitrary position is focused on as with the measurement of the average film thickness. In the focused cross section, one observation visual field region (length in a width direction: 40 μm) is focused on. In this event, the magnification of the FE-SEM only needs to be set to an appropriate magnification (for example, about 3000 times) so that the length of 40 μm falls within one field of view in the width direction. Then, the area proportion (namely, the area ratio) of the rust preventive pigment to the total area of the rust preventive paint film layer 20 in the observation visual field region having the above size is calculated by various functions installed in the electron microscope, image processing, or the like. The above observation can be performed on the observation visual field regions at ten arbitrary locations to obtain ten measured values of the area ratio of the rust preventive pigment. An average value of the ten measured values thus obtained is calculated and regarded as an average area ratio of the rust preventive pigment in the cross section. As explained above, the average area ratio is an average value of the area proportion occupied by the rust preventive pigment to the total area of the rust preventive paint film layer 20 in the observation visual field regions at the ten locations observed. The average value is regarded as the coverage ratio of the rust preventive pigment. Note that the rust preventive pigment in the paint film 11 can be identified by confirming existing elements by an EDS analysis (Nergy Dispersive X-ray Spectroscopy) for the particles existing in the paint film 11.

[Regarding the outermost layer paint film layer 30]

[0028] The outermost layer paint film layer 30 according to this embodiment is a resin coating layer which is located at the outermost layer of the paint film 11 as exemplified in FIG. 1A to FIG. 1C and has particles 101 existing in a dispersed state in a binder resin 103 as a film-forming component. The outermost layer paint film layer 30 may contain various additives such as a cross-linking agent, a coloring agent, and so on in addition to the above particles 101 and binder resin 103.

[0029] When a 60-degree specular glossiness Gs (60°) specified in JIS Z 8741:1997 is measured for the surface of the outermost layer paint film layer 30, a value of the 60-degree specular glossiness Gs (60°) is 20 or less. In the painted steel sheet 1 according to this embodiment, the surface of the outermost layer paint film layer 30 exhibits the glossiness in the above range, whereby the painted steel sheet 1 according to this embodiment exhibits a better matte appearance (eventually, better design). The value of the 60-degree specular glossiness Gs (60°) is more preferably 5 or more. Further, the value of the 60-degree specular glossiness Gs (60°) is more preferably 15 or less.

[0030] In the painted steel sheet 1 according to this embodiment, the particles 101 are dispersed in the binder resin 103 in the outermost layer paint film layer 30. In addition, the particles 101 satisfy the conditions explained in detail below. Thus, the binder resin 103 realizes predetermined corrosion resistance and flaw resistance. Further, the painted steel sheet 1 as a whole realizes excellent design having both a texture appearance and a matte appearance. Furthermore, lengthening the interface between the particle 101 and the binder resin 103 makes it possible to suppress the corrosion of the steel sheet. Secondarily, it becomes possible to prevent the generation of pressure marks due to relatively flattening of an organic coating at a deformed portion.

<<Regarding the particle 101>>

[0031] In the outermost layer paint film layer 30 according to this embodiment, the particles 101 project from positions of the surface at portions not containing the particles 101 of the outermost layer paint film layer 30. This can realize the excellent design having both a texture appearance and a matte appearance as a whole of the painted steel sheet 1. The details of the relation between the outermost layer paint film layer 30 and the particles 101 will be explained later.

[0032] Further, the particles 101 preferably have predetermined toughness and expandability. The particles 101 having the predetermined toughness and expandability can mitigate the impact applied to the outermost layer paint film layer 30. As a result of this, in the painted steel sheet 1 according to this embodiment, the flaw resistance of the outermost layer paint film layer 30 can be further improved. Further, the particles 101 having the predetermined toughness and expandability can further prevent the generation of the pressure marks due to relatively flattening of the organic coating at the deformed portion. Furthermore, if the outermost layer paint film layer 30 is flawed, it is possible to prevent the flaw from reaching the steel sheet 10 and maintain the corrosion resistance of the painted steel sheet 1.

[0033] Here, in the outermost layer paint film layer 30 according to this embodiment, any particles made of various raw

materials can be used as the particles 101 as long as they have the predetermined toughness and expandability. However, it is more preferable to use organic resin particles composed of an organic resin than inorganic particles composed of an inorganic resin represented by silica or ceramics from the viewpoint of having better toughness and expandability.

[0034] Examples of the organic resin particles to be used as the particles 101 include resin particles made of an acryl-based resin, resin particles made of a polyester-based resin, resin particles made of a urethane-based resin, resin particles made of a fluorine-based resin, resin particles made of a silicone resin, resin particles made of a polyolefin-based resin, and so on. It is more preferable to use, as the particles 101, the resin particles made of the urethane-based resin or the resin particles made of the acryl-based resin among them, from the viewpoint of more easily enabling the desired toughness and expandability. It is furthermore preferable to use, as the particles 101, resin particles using the acryl-based resin as a main component among them.

[0035] On the other hand, in the case of using particles of a thermoplastic resin as the resin particles, the particles preferably have a melting point at a level where they do not melt when a baking step is executed in a later-explained manufacturing process of the painted steel sheet. The particles 101 having the melting point can be made not to melt in the paint film baking step, resulting in the desired 60-degree specular glossiness Gs (60°). Though the baking will be explained later in detail, a peak metal temperature can be made to fall within a range of 180 to 250°C, and therefore the resin particles preferably have a melting point at a level exceeding the peak metal temperature.

[0036] Note that a plurality of types of particles having different average particle diameters may be contained as the particles 101. Further, the particles 101 may also have functions as various additives which can be added to the outermost layer paint film layer 30, such as the coloring agent, the rust preventive pigment, and so on.

<<Regarding the binder resin 103>>

[0037] Besides, as the binder resin 103 as the film-forming component contained in the outermost layer paint film layer 30 according to this embodiment, any raw material can be used as long as it has the function as the binder for the particles 101. However, from the viewpoints of ease of manufacturing and costs and the viewpoints of corrosion resistance and flaw resistance, it is preferable to use various types of organic resins as the binder resin 103. Examples of the binder resin 103 include an acryl-based resin, a polyester-based resin, a urethane-based resin, a fluorine-based resin, and so on. It is more preferable to use a binder resin containing an acryl-based resin or a polyester-based resin as a main component among them.

[0038] Further, in a preferred embodiment of the outermost layer paint film layer 30, an organic resin high in affinity with the particles 101 is selected as the binder resin 103. This can further improve the affinity between the particles 101 and the binder resin 103 and further suppress the fall-off of the particles 101. Further, it is possible to further improve the adhesiveness and barrier property of the outermost layer paint film layer 30. As an example of the resin particle high in affinity with the particles 101, a resin of the same type as the particles 101 is selected. Further, in the case of selecting the acrylic resin as the particles 101 as another example of the resin particle high in affinity with the particles 101, a polyester-based resin is selected as the binder resin 103.

[0039] In the case of selecting the acrylic resin as the particles 101 in another preferred embodiment of the outermost layer paint film layer 30, a binder resin containing a polyester/melamine curable resin as a main component is selected as the binder resin 103. Thus, the affinity between the binder resin 103 and the acryl-based resin as the particles 101 can further improve owing to the action of the melamine resin as a cross-linking agent (curing agent) used for cross-linking (curing) of the binder resin 103 to further suppress the fall-off of the particles 101. In a preferred embodiment, the binder resin 103 is composed of a polyester/melamine curable resin.

<Regarding the existing state of the particles 101 in the outermost layer paint film layer 30>

[0040] Next, a distribution state of the particles 101 in the outermost layer paint film layer 30 according to this embodiment will be explained in detail while referring to FIG. 2. FIG. 2 is an explanatory view for explaining the outermost layer paint film layer 30 in the painted steel sheet 1 according to this embodiment.

[0041] In the painted steel sheet 1 according to this embodiment, the particles 101 exist in a state of dispersing in the film-forming component such as the binder resin 103, the color pigment, and so on constituting the outermost layer paint film layer 30. For discussion of the existing state of the particles 101, a cross section obtained by cutting the paint film 11 according to this embodiment in a thickness direction at an arbitrary position is focused on as schematically illustrated in FIG. 2. Then, the cross section is observed under the FE-SEM and the existing state of the particles 101 will be discussed.

[0042] More specifically, a cross section obtained by cutting the paint film 11 according to this embodiment in a thickness direction at an arbitrary position is focused on, as with the above rust preventive paint film layer 20. In the focused cross section, a region having a length of 40 μm in a direction (hereinafter, also referred to as a width direction) perpendicular to the thickness direction is regarded as an observation visual field region in one-time microscope observation, and the observation visual field region is arbitrarily set at ten locations in the focused cross section. Then, based on obtained

measured results at the ten locations, a feature amount representing the existing state of the particles 101 explained below will be calculated.

◊ The coverage ratio of the particles 101 in the cross section

[0043] The coverage ratio of the particles 101 in the above cross section in the outermost layer paint film layer 30 according to this embodiment falls within a range of 5% or more and 30% or less in average value of the area ratio (namely, an average area ratio) being an area proportion of the particles 101 in the outermost layer paint film layer 30.

[0044] Here, the average area ratio is calculated as follows. Specifically, one observation visual field region (length in the width direction: 100 μm) is focused on in the cross section to be focused on. In this event, the magnification of the FE-SEM only needs to be set to an appropriate magnification (for example, about 1000 times) so that the length of 100 μm falls within one field of view in the width direction. Then, the area proportion (namely, the area ratio) of the particles 101 in the outermost layer paint film layer 30 in the observation visual field region having the above size is calculated by various functions installed in the electron microscope, image processing, or the like. The above observation can be performed on the observation visual field regions at ten arbitrary locations to obtain ten measured values of the area ratio of the particles 101. An average value of the ten measured values thus obtained is calculated and regarded as an average area ratio of the particles 101 in the cross section. As explained above, the average area ratio is an average value of the area proportions occupied by the particles to the total area of the observation visual field regions at the ten locations observed.

[0045] When the average area ratio of the particles 101 in the cross section is less than 5%, the coverage proportion of the particles 101 is too small, it is impossible to realize the desired design. When the average area ratio of the particles 101 is 5% or more, it becomes possible to realize an excellent design having both a texture appearance and a matte appearance. The average area ratio of the particles 101 in the cross section is preferably 10% or more and more preferably 15% or more.

[0046] On the other hand, when the average area ratio of the particles 101 in the cross section is more than 30%, the coverage proportion of the particles 101 is too large, thereby not only failing to realize the flaw resistance required for the outermost layer paint film layer 30 but also failing to realize the desired design (specifically, the matte appearance). When the average area ratio of the particles 101 is 30% or less, it becomes possible to realize the desired design while realizing the flaw resistance required for the outermost layer paint film layer 30. The average area ratio of the particles 101 in the cross section is preferably 25% or less and more preferably 20% or less.

◊ An average film thickness T of the outermost layer paint film layer 30 at portions not containing the particles 101

[0047] The average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101 in the above cross section in the outermost layer paint film layer 30 according to this embodiment is preferably 10 μm or more. Further, the average film thickness T is preferably 40 μm or less. When the average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101 in the cross section is less than 10 μm, the thickness of the outermost layer paint film layer 30 is too small, failing to realize the desired corrosion resistance. When the average film thickness T is 10 μm or more, it becomes possible to realize the corrosion resistance required for the painted steel sheet 1 according to this embodiment. The average film thickness T is more preferably 12 μm or more and furthermore preferably 15 μm or more.

[0048] On the other hand, when the average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101 in the cross section is more than 40 μm, the thickness of the outermost layer paint film layer 30 is too large, resulting in an undesirable decrease in the adhesiveness of the outermost layer paint film layer 30. When the average film thickness T is 40 μm or less, it is possible to realize the desired corrosion resistance while maintaining the adhesiveness of the outermost layer paint film layer 30. The average film thickness T is preferably 35 μm or less and more preferably 25 μm or less.

[0049] Note that the average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101 in the above cross section is specified by the following procedure. First, the cross section obtained by cutting the paint film 11 according to this embodiment in the thickness direction at the arbitrary position is focused on, as with the above rust preventive paint film layer 20. The thickness of the outermost layer paint film layer 30 at the portion where the particle 101 does not exist is measured at least at ten or more locations in the one focused observation visual field region. In this event, the thickness of the outermost layer paint film layer 30 at the portion not containing the particle 101 only needs to be measured using the length measurement function installed in the FE-SEM. Then, an average value of the three or more obtained measured values is calculated, and regarded as an average value of the thicknesses of the outermost layer paint film layer 30 in the focused observation visual field region. The above operation is performed for the observation visual field regions at ten arbitrary locations, and average values obtained respectively from the observation visual field regions are further averaged by the number of fields of view. The value obtained as above is regarded as an average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101.

[0050] It is assumed that measured results of thicknesses T_1, T_2, and T_3 have been obtained respectively at three locations at the portions where the particles 101 do not exist as illustrated in FIG. 2 in the one focused observation visual field region. In this case, an average value of the thicknesses of the outermost layer paint film layer 30 in the one focused observation visual field region is $(1/3) \times (T_1 + T_2 + T_3)$. This observation is executed for the observation visual field regions at ten arbitrary locations, and a plurality of obtained average values are further averaged by the number of fields of view, whereby the average film thickness T of the outermost layer paint film layer 30 at the portions not containing the particles 101 is obtained.

<<Regarding the existing state of the particles 101 in the outermost layer paint film layer 30>>

[0051] Next, an existing state of the particles 101 in the outermost layer paint film layer 30 will be explained in detail while referring to FIG. 2. FIG. 2 is a schematic view for explaining the particles 101 contained in the outermost layer paint film layer 30 in the painted steel sheet 1 according to this embodiment.

[0052] In the outermost layer paint film layer 30 according to this embodiment, an average particle diameter φ_{10} of the particles 101 specified by the procedure explained later (hereinafter, simply referred to as an "average particle diameter φ_{10}") is two times or more and five times or less the average film thickness T at the portions not containing the particles 101 of the outermost layer paint film layer 30 (hereinafter, simply referred to as an "average film thickness T"). The painted steel sheet 1 containing the particles 101 having the relation between the average particle diameter φ_{10} and the average film thickness T can realize the excellent design having both a texture appearance and a matte appearance as a whole. The particle 101 has an average particle diameter φ_{10} of the particles 101 that is preferably 2.1 times or more, more preferably 2.2 times or more, more preferably 2.3 times or more, more preferably 2.4 times or more, and most preferably 2.5 times or more the average film thickness T of the outermost layer paint film layer 30. Further, the particle 101 has an average particle diameter φ_{10} of the particles 101 that is preferably 4.5 times or less, more preferably 4 times or less, and most preferably 3.5 times or less the average film thickness T of the outermost layer paint film layer 30.

[0053] The above average particle diameter φ_{10} of the particles 101 in the cross section is specified by the following procedure. First, the cross section obtained by cutting the paint film 11 according to this embodiment in the thickness direction at the arbitrary position is focused on, as with the above rust preventive paint film layer 20. In the one focused observation visual field region, circle-equivalent diameters of the particles 101 are measured as measured values to be used for calculating the average particle diameter φ_{10} of the particles 101 existing in the region, and an average value of upper two circle-equivalent diameters in descending order of the circle-equivalent diameters of the particles 101 is calculated. This measurement is executed for the observation visual field regions at ten arbitrary locations, and average values respectively obtained from the observation visual field regions are further averaged by the number of fields of view. The thus-obtained value is regarded as the average particle diameter φ_{10} of the particles 101.

◊ A projecting portion peripheral length L_1 and a particle covered portion length L_2 in the cross section

[0054] Further, in the cross section obtained by cutting the paint film 11 in the thickness direction at the arbitrary position, a projecting portion of the particle 101 projecting from a position on the surface at the portion not containing the particle 101 of the outermost layer paint film layer 30 (hereinafter, referred to as a "projecting portion P") is covered, at half or more of a length along an outer peripheral portion of the projecting portion (hereinafter, referred to as a "projecting portion peripheral length L_1"), with the film-forming component having a thickness of 0.5 μm or more.

[0055] In the example illustrated in FIG. 2, a portion located above a segment B of a dotted line obtained by linking positions of the surface of the outermost layer paint film layer 30 at portions where the particles 101 do not exist is the projecting portion P. Besides, a portion of the particle 101 covered with the film-forming component having a thickness of 0.5 μm or more of the projecting portion P is called a "particle covered portion C" and a portion of the particle 101 not covered with the film-forming component having a thickness of 0.5 μm or more is called a "particle exposed portion E". The above "projecting portion P of the particle 101 is covered, at half or more of a length along an outer peripheral portion of the projecting portion P, with the film-forming component" means, in other words, that a ratio (L_2/L_1) of the length of the particle covered portion C along the outer peripheral portion of the projecting portion P (hereinafter, referred to as a "particle covered portion peripheral length L_2") to the projecting portion peripheral length L_1 is 1/2 or more. Note that all the projecting portion P may be covered with the film-forming component, as the particle 101 illustrated on the right side in FIG. 2. In this case, the projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 are equal, and the above ratio (L_2/L_1) is 1.

[0056] In the outermost layer paint film layer 30 according to this embodiment, half or more of the projecting portion P of the particle 101 is covered with the film-forming component, so that the interface between the particle 101 and the film-forming component can be lengthened. Therefore, in the painted steel sheet 1 according to this embodiment, it is possible to suppress the intrusion of a corrosion factor from the interface and to suppress the corrosion on the surface of the steel sheet 10. From these viewpoints, the ratio (L_2/L_1) between the projecting portion peripheral length L_1 and the particle

covered portion peripheral length L_2 is preferably 3/5 or more.

[0057] The projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 in the cross section are specified by the following procedure. First, the cross section obtained by cutting the paint film 11 according to this embodiment in the thickness direction at the arbitrary position is focused on, as with the above rust preventive paint film layer 20. All of the particles 101 each having the particle exposed portion E are specified in the visual field in the focused cross section. Here, it is clear that the particle 101 not having the particle exposed portion E (for example, the particle 101 on the right side in FIG. 2) has the above ratio (L_2/L_1) of 1 because the projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 are equal, and therefore the measurement therefore is omitted. For each of the specified particles 101 each having the particle exposed portion E, the line segment B of the dotted line obtained by linking positions of the surface of the outermost layer paint film layer 30 at portions where the particles 101 do not exist is defined. The length of an arc linking two intersection points between the line segment B and the outer periphery of the particle 101 is measured and regarded as the projecting portion peripheral length L_1. Further, a length L_{21} of an arc linking a left one of the two intersection points between the line segment B and the outer periphery of the particle 101 and a left one of two points on the outer periphery of the particle 101 at the boundary between the particle covered portion C and the particle exposed portion E, and a length L_{22} of an arc linking a right one of the two intersection points between the line segment B and the outer periphery of the particle 101 and a right one of the two points on the outer periphery of the particle 101 at the boundary between the particle covered portion C and the particle exposed portion E are measured, and a length obtained by adding the lengths L_{21} and L_{22} of the arc is regarded as the particle covered portion peripheral length L_2. The projecting portion peripheral length L_1 and the lengths L_{21} and L_{22} of the arc can be calculated by various functions installed in the electron microscope, image processing, or the like. Further, the above ratio (L_2/L_1) is calculated. When the above ratio (L_2/L_1) calculated in this manner for each of the particles 101 is 1/2 or more, it can be said that "the projecting portion P of the particle 101 is covered, at half or more of a length along an outer peripheral portion of the projecting portion P, with the film-forming component". Note that a point G in FIG. 2 is the center of gravity of the particle 101.

[0058] Note that a percentage of the particles 101 each having the above ratio (L_2/L_1) between the projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 of 1/2 or more is most preferably 100%. However, it is considered that the one whose particle exposed portion E is expanded due to the use state or the one exceptionally having the above ratio (L_2/L_1) outside the above prescribed range may be contained. Therefore, the percentage of the particles 101 each having the above ratio (L_2/L_1) between the projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 of 1/2 or more may be 60% or more, and more preferably 80% or more.

◊ An average particle diameter of all of the particles 101

[0059] The average particle diameter φ_{10} of the particles 101 has the above configuration, and the average particle diameter of all of the particles 101 is preferably 15 μm or more when the film thickness of the rust-proof paint film is 10 μm. Further, the average particle diameter of all of the particles 101 is preferably 40 μm or less when the film thickness of the rust-proof paint film is 10 μm. When the average particle diameter of all of the particles 101 is less than 15 μm, the average particle diameter of the particles 101 is too small, failing to realize the desired design and flaw resistance. When the average particle diameter of all of the particles 101 is 15 μm or more, it is possible to realize the design and flaw resistance required for the painted steel sheet 1 according to this embodiment. The average particle diameter of the particles 101 is more preferably 18 μm or more, and furthermore preferably 20 μm or more.

[0060] On the other hand, when the average particle diameter of the particles 101 is more than 40 μm, the average particle diameter of the particles 101 is too large, possibly resulting in a lack or the like of the particles in the manufacturing process. When the average particle diameter of the particles 101 is 40 μm or less, it is possible to suppress a lack of particles and realize stable manufacturing. The average particle diameter of the particles 101 is more preferably 30 μm or less.

[0061] The average particle diameter of all of the particles 101 can be measured as with the average particle diameter φ_{10} of upper ten particles 101. Specifically, in the one observation visual field when calculating the average particle diameter φ_{10}, the average value of the circle-equivalent diameters of all of the particles 101 in the observation visual field is calculated. This measurement is executed for the observation visual field regions at ten arbitrary locations, and average values obtained respectively from the observation visual field regions are further averaged by the number of fields of view. The thus-obtained value is regarded as the average particle diameter of all of the particles 101.

◊ A ratio between a minimum film thickness and a maximum film thickness of the outermost layer paint film layer 30

[0062] In the outermost layer paint film layer 30 according to this embodiment, a ratio (H_{MAX}/H_{min}) of a maximum film thickness H_{MAX} to a minimum film thickness H_{min} specified by the following procedure is preferably 5 or more and 20 or less. When the ratio (H_{MAX}/H_{min}) is within the above range, the value of the 60-degree specular glossiness Gs (60°) of the outermost layer paint film layer 30 can be made more preferable one. This exhibits a better matte appearance (eventually,

a better design). Further, when the ratio (H_{MAX}/H_{min}) is set to 5 or more, the tactile impression of the surface of the painted steel sheet 1 can be more preferable. From the viewpoint, the ratio (H_{MAX}/H_{min}) of the maximum film thickness H_{MAX} is more preferably 6 or more, and furthermore preferably 7.5 or more. Further, the ratio (H_{MAX}/H_{min}) is more preferably 17.5 or less, and furthermore preferably 15 or less.

[0063] Besides, when the ratio (H_{MAX}/H_{min}) is within the above range, a portion of the minimum film thickness H_{min} in the outermost layer paint film layer 30 may be a thin film portion. In this case, when a flaw or the like occurs at the thin film portion, a corrosion factor is likely to intrude through the flaw. In contrast to this, in the painted steel sheet 1 according to this embodiment, the rust preventive paint film layer 20 is provided and thus can suppress the corrosion on the surface of the steel sheet 10 even if the corrosion factor intrudes.

[0064] The ratio (H_{MAX}/H_{min}) of the maximum film thickness H_{MAX} to the minimum film thickness H_{min} is specified by the following procedure. First, the cross section obtained by cutting the paint film 11 according to this embodiment in the thickness direction at the arbitrary position is focused on, as with the above rust preventive paint film layer 20. In the one focused observation visual field region, a portion of a local minimum film thickness h_{min} and a portion of a local maximum film thickness h_{MAX} are specified using, for example, the length measurement function installed in the FE-SEM or the like, and their film thicknesses are measured. The above operation is performed for the observation visual field regions at ten arbitrary locations. Then, a smallest value among the local minimum film thicknesses h_{min} obtained respectively from the observation visual field regions is regarded as the minimum film thickness H_{min} and a largest value among the local maximum film thicknesses h_{MAX} is regarded as the maximum film thickness H_{MAX}. Further, the ratio (H_{MAX}/H_{min}) of the maximum film thickness H_{MAX} to the minimum film thickness H_{min} is specified from the obtained values.

[0065] Here, as exemplified in FIG. 2B, the portion of the local minimum film thickness h_{min} is a portion where the outermost layer is thinnest in each visual field, that is, a portion where the distance between a surface on a side in contact with the rust preventive paint film layer 20 and an exposed surface S is shortest. Besides, a portion of the local maximum film thickness h_{MAX} is a portion where the film thickness of the outermost layer paint film layer 30 is largest in each visual field, that is, a portion where the distance between a surface on a side in contact with the rust preventive paint film layer 20 and the exposed surface S is largest. However, the above "distance" is in a direction perpendicular to the in-plane direction of the steel sheet 10.

[0066] Note the "exposed surface S" in the outermost layer paint film layer 30 includes an exposed surface Sa of the binder resin 103 at the portion where the particle 101 does not exist, an exposed surface Sb of the particle exposed portion E of the particle 101, and an exposed surface Sc of the binder resin 103 at the particle covered portion C. For example, portions of h_1 to h_4 indicating the film thicknesses of the outermost layer paint film layer 30 as illustrated in FIG. 2B are considered. In this case, at the portions of the film thickness h_1 and the film thickness h_3, the distances between the surface on the side in contact with the rust preventive paint film layer 20 and the exposed surface Sa of the binder resin 103 at the portions where the particles 101 do not exist are the thicknesses h_1, h_3, respectively. Besides, at the portion of the film thickness h_2, the distance between the surface on the side in contact with the rust preventive paint film layer 20 and the exposed surface Sb at the particle exposed portion E is the thickness h_2. Besides, at the portion of the film thickness h_4, the distance between the surface on the side in contact with the rust preventive paint film layer 20 and the exposed surface Sc of the binder resin 103 at the particle covered portion C is the thickness h_4.

[0067] For specifying the local minimum film thickness h_{min} and the local maximum film thickness h_{MAX} in the example of FIG. 2B, the largest one of the film thicknesses h_1 to h_4 is h_2, and therefore this portion is specified as the portion of the local maximum film thickness H_{MAX}. Besides, the smallest one is h_3, and therefore this portion is specified as the portion of the local minimum film thickness h_{min}. In the observation of the cross section, the local minimum film thickness h_{min} and the local maximum film thickness h_{MAX} are specified in the above manner.

<<Regarding another configuration of the outermost layer paint film layer 30>>

[0068] The outermost layer paint film layer 30 can take another desired configuration not containing the particles 101 as long as the value of the 60-degree specular glossiness Gs (60°) of the outermost layer paint film layer 30 is 20% or less.

[0069] In one embodiment, the outermost layer paint film layer 30 can include a thin film part 200 in the observation of the cross section obtained by cutting the paint film 11 in the thickness direction at the arbitrary position. FIG. 3A and FIG. 3B are cross-sectional views illustrating the configuration of the painted steel sheet 1 including the outermost layer paint film layer 30 including the thin film part 200. When a flaw or the like occurs in the thin film part 200, a corrosion factor is likely to intrude through the flaw. In contrast to this, in the painted steel sheet 1 according to this embodiment, the rust preventive paint film layer 20 is provided and therefore can suppress the corrosion at the surface of the steel sheet 10 even if the corrosion factor intrudes.

[0070] Regarding the thin film part 200, in the example of FIG. 3A, when the upper surface of the steel sheet 10 is a flat shape and the upper surface of the outermost layer paint film layer 30 is a rough surface shape having certain recesses and projections, a portion between the painted steel sheet 1 and a recess of the outermost layer paint film layer 30 corresponds to the thin film part 200. The thin film part 200 in this case is 20 μm or less as an example. An example of the conceivable

case that the outermost layer paint film layer 30 has a rough surface shape having the certain recesses and projections is a case where the outermost layer paint film layer 30 contains 1% or more of a curing catalyst and the outermost layer paint film layer 30 thus cures and shrinks to have the recesses and projections.

[0071] Besides, in the example of FIG. 3B as another example, when the upper surface of the steel sheet 10 has a rough surface shape having certain recesses and projections and the upper surface of the outermost layer paint film layer 30 has a flat shape, a portion between a projection of the painted steel sheet 1 and the outermost layer paint film layer 30 may correspond to the thin film part 200. The thin film part 200 in this case is 20 μm or less as an example. An example of the conceivable case that the painted steel sheet 1 has a rough surface shape having the certain recesses and projections is a case where the surface roughness of the painted steel sheet 1 is 2 μm or more in Ra.

(Regarding the manufacturing method of the painted steel sheet)

[0072] Next, an example of the manufacturing method of the painted steel sheet according to this embodiment will be explained.

[0073] First, various pre-treatments including an alkali degreasing treatment, a washing treatment, a pickling treatment, and so on are performed on the steel sheet being the base material to make a clean steel sheet surface.

[0074] Then, various known rust preventive paints for forming a rust preventive paint film layer are applied to the steel sheet and dried. Here, the application of the above rust preventive paint can be performed by generally known coating methods such as roll coating, curtain flow coating, air spraying, airless spraying, immersion, bar coating, brushing, and the like. Besides, the heating method of the rust preventive paint is not particularly limited and, for example, any method such as hot air, near-infrared ray, far-infrared ray, induction heating, and a heating method by combination of them may be employed.

[0075] Next, a coating solution for forming an organic resin coating layer to the surface of the steel sheet formed with the rust preventive paint film layer and dried by heating to form the organic resin coating layer. Here, the coating solution is prepared by incorporating the above binder resin and various additives as necessary into a solvent. The above particles may be incorporated in the coating solution to be applied to at least one surface of the steel sheet as necessary to form the outermost layer paint film layer 30. Further, as necessary, a coating solution for forming another organic resin coating layer may be applied to the surface of the rust preventive paint film layer to form an outermost layer paint film layer on the surface of the other organic resin coating layer.

[0076] Besides, it is important to perform the application of the prepared coating solution using a curtain flow coater. By applying the coating solution containing particles using the curtain flow coater, it is possible to apply the coating solution without precipitating particles or causing paint defect (roping).

[0077] After the coating solution is applied to the surface of the rust preventive paint film layer, baking of heat-curing the coating solution is performed. In the baking, the heating temperature may be set according to the solvent to be used and is preferably set to, for example, a range of 180 to 250°C as a peak metal temperature. Further, when heat-curing the coating solution, it is necessary to pay attention to a temperature increasing rate. More specifically, it is important to set the temperature increasing rate to a range of 5 to 50 °C/sec. By applying the coating solution having the above surface tension and viscosity by the curtain flow coater and heat-curing it under a situation of the above temperature increasing rate, the organic resin coating layer in which the above-explained state of the particles is realized can be formed. The temperature increasing rate is more preferably in a range of 10 to 30 °C/sec.

[0078] Note that the heating method of the coating solution is not particularly limited but, for example, any method such as hot air, near-infrared ray, far-infrared ray, induction heating, and a heating method by a combination of them may be employed.

[0079] The manufacturing method of the painted steel sheet according to this embodiment has been explained above.

EXAMPLES

[0080] Hereinafter, the painted steel sheet according to this embodiment will be concretely explained with examples and comparative examples. Note that the following examples are merely examples of the painted steel sheet according to this embodiment and the painted steel sheet according to this embodiment is not limited to the following examples.

(1) Steel sheet

[0081] Five types of steel sheets of A1 to A5 listed in Table 1 below were prepared (all of them are commercially available). The plating weight is a weight per one side in Table 1 below. For the prepared steel sheets, a plated steel sheet (sheet thickness of 0.6 mm) made by performing a chromate-free-based paint base treatment (equivalent to CT-E300/Nippon Parkerizing Co., Ltd.) of 60 mg/m^2 was also prepared. A treatment solution used for the paint base treatment contains a silane coupling agent as its component, and a coating layer formed by the paint base treatment

functions as a paint base treatment coating layer. Note that the presence or absence of the paint base treatment is listed in Tables 4-1 to 4-3 below.

(2) Rust preventive paint film layer

[0082] First, clear rust preventive paints B1 to B3 below containing no rust preventive pigment were prepared by the following procedure. Then, any one or two or more of rust preventive pigments C1 to C5 listed in Table 2 were added and subjected to pigment dispersion to produce rust preventive paints. In the case of using the clear rust preventive paint B1, the polyester resin and the epoxy resin contained therein mainly function as the binder resin in the rust preventive paint film layer. In the case of using the clear rust preventive paint B2, the polyester resin contained therein mainly functions as the binder resin in the rust preventive paint film layer. In the case of using the clear rust preventive paint B3, the polyester resin and the urethane resin contained therein mainly function as the binder resin in the rust preventive paint film layer. After the produced rust preventive paints were used and applied to the one side of the steel sheet subjected to the base treatment by a bar coater, and then baked at a PMT (steel sheet peak metal temperature) of 220°C±10°C and for a baking time of 10 seconds. The types and the coverage ratios (%) of the rust preventive pigments C1 to C5 of the produced rust preventive paint films and the total coverage ratio (%) obtained by adding the coverage ratios of all contained rust preventive pigments are listed in Tables 4-1 to 4-3. Further, the film thickness (μm) of the rust preventive paint film is listed in Tables 4-1 to 4-3. In Table 2, "SHIELDEX" is a registered trademark, "K-WHITE" is a registered trademark, and "Kyowamag" is a registered trademark.

<Clear rust preventive paint: B1>

[0083] It was produced by blending a polyester resin (VYLON TM270 manufactured by TOYOBO. CO., LTD, "VYLON" is a registered trademark), an epoxy resin (EPICLON TM1000 manufactured by DIC, "EPICLON" is a registered trademark), and a melamine resin as a cross-linking agent (CYMEL 327 manufactured by allnex, "CYMEL" is a registered trademark) at a solid content ratio of 75:5:20 and adding an organic solvent (using a mixture of cyclohexanone:Solvesso 150 = 1:1 in mass ratio) so that a solid content concentration was 25 mass% for adjustment.

<Clear rust preventive paint: B2>

[0084] It was produced by blending a polyester resin (VYLON GK-140 manufactured by TOYOBO. CO., LTD) and a melamine resin as a cross-linking agent (CYMEL 327 manufactured by allnex) at a solid content ratio of 80:20 and adding an organic solvent (using a mixture of cyclohexanone: Solvesso 150 = 1:1 in mass ratio) so that a solid content concentration was 25 mass% for adjustment.

<Clear rust preventive paint: B3>

[0085] It was produced by blending a polyester resin (VYLONAL MD1480 manufactured by TOYOBO. CO., LTD, "VYLONAL" is a registered trademark), a urethane resin (SUPERFLEX 150 manufactured by DKS Co. Ltd., "SUPERFLEX" is a registered trademark), and a melamine resin as a cross-linking agent (CYMEL 327 manufactured by allnex) at a solid content ratio of 40:40:20 and adding water so that a solid content concentration was 25 mass% for adjustment.

(3) Outermost layer paint film layer

[0086] A paint used as the outermost layer paint film was "FLC 100 HQ (white type)" manufactured by Nippon Paint Co., Ltd. being a commercially available polyester-based overcoat coating paint as the binder resin. The outermost layer paint film was produced by adding a predetermined amount of any one or two or more of resin particles D1 to D10, D13, or D14 listed in Table 3, silica D11 as an aggregate, and a curing catalyst D12 to the paint for adjustment. Note that the viscosity was adjusted by adding an organic solvent (using a mixture of cyclohexanone:Solvesso 150 = 1:1 in mass ratio) according to the viscosity of the produced paint. The produced paint was used and applied to the one side of the steel sheet applied with the rust preventive paint film by a curtain coater or a bar coater. In the case of the curtain coater, after the application by the curtain coater, baking was performed at a PMT (steel sheet peak metal temperature) of 230°C and for a baking time of 40 seconds. Also in the case of the bar coater, baking was similarly performed at a PMT (steel sheet peak metal temperature) of 230°C and for a baking time of 12 seconds. In some samples, the baking was performed with the baking time changed while keeping the PMT at 230°C. The coating methods used are listed in Table 5-1 to Table 5-3. The rust preventive paint film and the outermost layer paint film were applied only on the front surface, or both of the front surface and the rear surface. The presence or absence and the type of the coating film on the rear surface are listed in Table 5. In Table 3, "GRANPEARL" is a registered trademark and "Sylosphere" is a registered trademark.

[0087] A resin particle coverage ratio (%) of each of the produced outermost layer paint film layers and a total coverage ratio (%) obtained by adding all of the contained resin particles are listed in Table 5-1 to Table 5-3. Further, the film thickness T (μm) of the outermost layer paint film and the ratio (particle diameter/film thickness) between the average particle diameter φ_{10} and the average film thickness T are listed in Table 5-1 to Table 5-3. Further, in Table 5-1 to Table 5-3, the one having a percentage of the above ratio (L_2/L_1) between the projecting portion peripheral length L_1 and the particle covered portion peripheral length L_2 in each resin particle of 1/2 or more of 60% or more is indicated with "o" as being excellent in resin particle coverage, and the one having the percentage of less than 60% is indicated with "×" as not being excellent in resin particle coverage. Further, the ratio of the maximum film thickness to the minimum film thickness of the outermost layer paint film layer (maximum film thickness/minimum film thickness) is listed in Table 5-1 to Table 5-3.

[0088] For each of the obtained sample materials, the glossiness (more specifically, the 60-degree specular glossiness Gs (60°)) was measured according to the above-explained method, and is listed in Table 6-1 to Table 6-3 below.

[0089] Further, the corrosion resistance (corrosion resistance 1), the end face corrosion resistance (corrosion resistance 2), and so on on the paint film formation surface were measured. Further, the flaw resistance on the paint film formation surface was evaluated. The obtained results are collectively listed in Table 6-1 to Table 6-3 below. The evaluation method is as follows.

(Corrosion resistance 1)

[0090] For the corrosion resistance (corrosion resistance 1) on the paint film formation surface, the end face of the surface treated steel sheet was sealed with tape, a cross cut reaching a steel sheet base material was applied to a test piece central portion with a cutter, and then an average paint film blister width from a cut part after execution of a salt spray (SST, 5% NaCl, 35° atmosphere) for 500 hr was measured and calculated. Note that the average paint film blister width can be calculated by measuring the area of a paint film blister part and then dividing it by a cut part length. Further, evaluation criteria are as follows. The acceptable level was set to 3 or higher.

<Evaluation criteria>

[0091] Grade 5: less than 0.5 mm and no red rust generation

4: 0.5 mm or more and less than 1 mm and no red rust generation
3: 1 mm or more and less than 2 mm and no red rust generation
2: 2 mm or more and less than 5 mm and no red rust generation
1: 5 mm or more or red rust generation

(Corrosion resistance 2)

[0092] For the end face corrosion resistance (corrosion resistance 2), the upper and lower end faces of the surface treated steel sheet were sealed with tape in a sample material having the rust preventive paint film and the outermost layer paint film formed on both the front surface and the rear surface, and then average paint film blister widths from right and left end face portions (left: lower burr, right: upper burr) after execution of a salt spray (SST, 5% NaCl, 35° atmosphere) for 500 hr were measured and calculated. Note that the average paint film blister width can be calculated by measuring the area of a paint film blister part and then dividing it by an end face part length. Further, evaluation criteria are as follows. The acceptable level was set to 2.

<Evaluation criteria>

[0093] Grade 2: average blister width of less than 5 mm and no red rust generation

1: average blister width of 5 mm or more or red rust generation

(Flaw resistance)

[0094] For the flaw resistance on the paint film formation surface, the flaw resistance was evaluated by a coin scratch test. A coin was brought into contact, in a state of being inclined at 45 degrees, with the painted surface of a produced sample, and scratched it with a load of 500 g. An applied flaw was evaluated on the basis of the following criteria, and the acceptable level was set to 3 or higher.

<Evaluation criteria>

[0095] Grade 4: No paint film peeling or very slight paint film peeling is observed.

3: Slight paint film peeling is observed.
2: Partial paint film peeling is observed.
1: Paint film is completely peeled.

(Roughness measurement)

[0096] A roughness (arithmetic mean roughness Ra) obtained from the surface of the painted steel sheet was obtained by a contact-type roughness gauge compliant with JIS B 0601: 2001. The measured length was set to 8.0 mm and the cutoff value was set to 0.8 mm. Ra of 2 μm or more was regarded as ◦ and Ra of less than 2 μm was regarded as ×.

(Fall-off inspection of the particle)

[0097] A sample containing the resin particles in the outermost layer paint film layer was subjected to cylindrical drawing (drawing conditions: blank diameter of 100 mmφ, punch diameter of 50 mmφ, die diameter of 52.4 mmφ, and blank holder force (BHF) of 1.5 ton) so that a test surface (painted surface) was the outer surface, and then the presence or absence of flaw generation on the cylindrical drawn wall surface was visually confirmed. Regarding a flaw generation site where the flaw generation was confirmed, a wall portion including a flaw portion was cut out and confirmed whether the fall-off of the resin particles occurred by the surface SEM observation. The one in which the flaw generation on the wall portion was not confirmed or the one in which the flaw generation was confirmed but the fall-off of the resin particles did not occur was regarded as◦, and the one in which the flaw generation was confirmed and the occurrence of the fall-off of the resin particles was confirmed was regarded as ×.

[Table 1]

[0098]

TABLE 1

TYPE	METAL SHEET (HEREINAFTER, % REPRESENTS MASS%)
A1	HOT-DIP GALVANIZED STEEL SHEET (PLATING WEIGHT 60 g/m2 ON ONE SIDE)
A2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET (Fe: 10%) (PLATING WEIGHT 50 g/m2 ON ONE SIDE)
A3	HOT-DIP Al-9% Si PLATED SHEET SHEET (PLATING WEIGHT 60 g/m2 ON ONE SIDE)
A4	HOT-DIP Zn-11% Al-3% Mg-0.2% Si PLATED SHEET SHEET (PLATING WEIGHT 100 g/m2 ON ONE SIDE)
A5	STEEL SHEET (WITHOUT PLATING)

[Table 2]

[0099]

TABLE 2

TYPE	RUST PREVENTIVE PIGMENT
C1	Ca ION-EXCHANGED SILICA "SHIELDEX C303" MANUFACTURED BY GRACE INC., CONTAINING Si
C2	ALUMINIUM DIHYDROGEN TRIPHOSPHATE SUBJECTED TO Mg TREATMENT "K-WHITE G105" MANUFACTURED BY TAYCA CORPORATION, CONTAINING Mg, P
C3	ALUMINIUM DIHYDROGEN TRIPHOSPHATE "K-WHITE #82" MANUFACTURED BY TAYCA CORPORATION, CONTAINING P
C4	MAGNESIUM OXIDE "KYOWAMAG MF-30" MANUFACTURED BY KYOWA CHEMICAL INDUSTRY CO .,LTD., CONTAINING Mg

(continued)

TYPE	RUST PREVENTIVE PIGMENT
C5	CALCIUM VANADATE GENERAL REAGENT CONTAINING V

[Table 3]

TYPE		RESIN PARTICLE, AGGREGATE, OR CURING CATALYST
D1	RESIN PARTICLE	"MX-150" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 1.5 μm) MANUFACTURED BY SOKEN CHEMICAL ENGINEERING CO., LTD.
D2	RESIN PARTICLE	"MX-300" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 3 μm) MANUFACTURED BY SOKEN CHEMICAL ENGINEERING CO., LTD.
D3	RESIN PARTICLE	"MX-500L" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 5 μm) MANUFACTURED BY SOKEN CHEMICAL ENGINEERING CO., LTD.
D4	RESIN PARTICLE	"MX-1000" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 10 μm) MANUFACTURED BY SOKEN CHEMICAL 6 ENGINEERING CO., LTD.
D5	RESIN PARTICLE	"MX-2000" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 20 μm) MANUFACTURED BY SOKEN CHEMICAL ENGINEERING CO., LTD.
D6	RESIN PARTICLE	"MX-3000" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 30 μm) MANUFACTURED BY SOKEN CHEMICAL ENGINEERING CO., LTD.
D7	RESIN PARTICLE	"GRANPEARL GU-0700P" (URETHANE RESIN-BASED PARTICLE, AVERAGE PARTICLE DIAMETER 7 μm) MANUFACTURED BY AICA KOGYO COMPANY, LIMITED
D8	RESIN PARTICLE	"GRANPEARL GU-2000P" (URETHANE RESIN-BASED PARTICLE, AVERAGE PARTICLE DIAMETER 20 μm) MANUFACTURED BY AICA KOGYO COMPANY, LIMITED
D9	RESIN PARTICLE	"FLOW BEAD CL-2080" (POLYETHILENE PARTICLE (MELTING POINT 105°C, AVERAGE PARTICLE DIAMETER 11 μm)) MANUFACTURED BY SUMITOMO SEIKA CHEMICALS CO.,LTD.
D10	RESIN PARTICLE	"FLOW BEAD PR" (POLYPROPYLENE PARTICLE (MELTING POINT 150°C, AVERAGE PARTICLE DIAMETER 10 μm)) MANUFACTURED BY SUMITOMO SEIKA CHEMICALS CO.,LTD.
D11	AGGREGATE	"SYLOSPHERE C-1510" (SILICA PARTICLE, AVERAGE PARTICLE DIAMETER 10 μm) MANUFACTURED BY FUJI SILYSIA CHEMICAL LTD.
D12	CURING CATALYST	"NACURE DDBSA SERIES 5225" (SODIUM DODECYLBENZENESULFONATE) MANUFACTURED BY KUSUMOTO CHEMICALS, LTD.
D13	RESIN PARTICLE	"MBX-50" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 50 μm) MANUFACTURED BY SEKISUI PLASTICS CO., LTD.
D14	RESIN PARTICLE	"MBX-100" (ACRYLIC RESIN PARTICLE, AVERAGE PARTICLE DIAMETER 100 μm) MANUFACTURED BY SEKISUI PLASTICS CO., LTD.

[Table 4-1]

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM										REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT								
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4		TOTAL COVERAGE **RATIO** (%)	
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		
1	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
2	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
3	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
4	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
5	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
6	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
7	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
8	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
9	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
10	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
11	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
12	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
13	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
14	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
15	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
16	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
17	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE

(continued)

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM											REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT								TOTAL COVERAGE **RATIO** (%)	
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4			
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		
18	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
19	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
20	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
21	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
22	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
23	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
24	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
25	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
26	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
27	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
28	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
29	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
30	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
31	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
32	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
33	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE

(continued)

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM											REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT									
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4		TOTAL COVERAGE **RATIO** (%)	
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		
34	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
35	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
36	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
37	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
38	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE

[Table 4-2]

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM										REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT								
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4		TOTAL COVERAGE RATIO (%)	
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		
39	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
40	A1	PRESENT	B1	1	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
41	A1	PRESENT	B1	2	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
42	A1	PRESENT	B1	5	C1	20	C2	20	C5	5			45	EXAMPLE
43	A1	PRESENT	B1	7	C1	20	C2	20	C5	5			45	EXAMPLE
44	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
45	A1	PRESENT	B1	12	C1	20	C2	20	C5	5			45	EXAMPLE
46	A1	PRESENT	B1	15	C1	20	C2	20	C5	5			45	EXAMPLE
47	A1	PRESENT	B1	20	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
48	A1	PRESENT	B1	10	C1	4	C2	3	C5	3			10	COMPARATIVE EXAMPLE
49	A1	PRESENT	B1	10	C1	7	C2	7	C5	6			20	COMPARATIVE EXAMPLE
50	A1	PRESENT	B1	10	C1	10	C2	10	C5	10			30	EXAMPLE
51	A1	PRESENT	B1	10	C1	14	C2	14	C5	14			42	EXAMPLE
52	A1	PRESENT	B1	10	C1	15	C2	15	C5	15			45	EXAMPLE
53	A1	PRESENT	B1	10	C1	17	C2	17	C5	17			51	EXAMPLE
54	A1	PRESENT	B1	10	C1	20	C2	20	C5	20			60	EXAMPLE
55	A1	PRESENT	B1	10	C1	25	C2	25	C5	25			75	COMPARATIVE EXAMPLE
56	A1	PRESENT	B1	10	C1	20	C2	15	C5	10			45	EXAMPLE

(continued)

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM										REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT								
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4		TOTAL COVERAGE RATIO (%)	
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		
57	A1	PRESENT	B1	10	C1	15	C2	20	C5	10			45	EXAMPLE
58	A1	PRESENT	B1	10	C1	15	C3	15	C4	10	C5	5	45	EXAMPLE
59	A1	PRESENT	B1	10	C1	50							50	EXAMPLE
60	A1	PRESENT	B1	10	C2	50							50	EXAMPLE
61	A1	PRESENT	B1	10	C3	50							50	EXAMPLE
62	A1	PRESENT	B1	10	C4	50							50	EXAMPLE
63	A1	PRESENT	B1	10	C5	50							50	EXAMPLE
64	A1	ABSENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
65	A2	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
66	A3	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
67	A4	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
68	A	PRESENT	B1	10	C1	20	C2	20	C5	5			45	COMPARATIVE EXAMPLE
69	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
70	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
71	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
72	A1	PRESENT	B2	10	C1	20	C2	20	C5	5			45	EXAMPLE
73	A1	PRESENT	B3	10	C1	20	C2	20	C5	5			45	EXAMPLE
74	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
75	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE

[Table 4-3]

No	METAL SHEET	PAINT BASE	RUST PREVENTIVE PAINT FILM										REMARKS
			CLEAR PAINT TYPE	FILM THICKNESS (μm)	RUST PREVENTIVE PIGMENT								
					RUST PREVENTIVE PIGMENT 1		RUST PREVENTIVE PIGMENT 2		RUST PREVENTIVE PIGMENT 3		RUST PREVENTIVE PIGMENT 4		TOTAL COVERAGE RATIO (%)	
					TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE **RATIO** (%)		
76	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
77	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
78	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
79	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
80	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
81	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
82	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
83	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
84	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
85	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
86	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
87	A4	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
88	A4	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
89	A4	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
90	A4	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
91	A4	PRESENT	**B1**	10	C1	20	C2	20	C5	5			45	EXAMPLE
92	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
92	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE
92	A1	PRESENT	B1	10	C1	20	C2	20	C5	5			45	EXAMPLE

[Table 5-1]

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
1	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
2	CURTAIN	10	12					Q			0.0		○			COMPARATIVE EXAMPLE
3	CURTAIN	10	12	D6	1			1			18		○			COMPARATIVE EXAMPLE
4	CURTAIN	10	12	D6	2			2			2.4		○			EXAMPLE
5	CURTAIN	10	12	D6	5			5			3.0		○			EXAMPLE
6	CURTAIN	10	12	D6	10			10			3.0		○			EXAMPLE
7	CURTAIN	10	12	D6	20			20			3.2		○			EXAMPLE
8	CURTAIN	10	12	D6	30			30			3.3		○			EXAMPLE
9	CURTAIN	10	12	D6	35			35			3.2		○			EXAMPLE
10	CURTAIN	10	12	D1	15			15			0.2		○			COMPARATIVE EXAMPLE
11	CURTAIN	10	12	D2	15			15			0.4		○			COMPARATIVE EXAMPLE
12	CURTAIN	10	12	D3	15			15			0.5		○			COMPARATIVE EXAMPLE
13	CURTAIN	10	12	D4	15			15			1.1		○			COMPARATIVE EXAMPLE

(continued)

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
14	CURTAIN	10	12	D5	15			15			2.1		○			EXAMPLE
15	CURTAIN	10	12	D6	10	D3	5	15			3.1		○			EXAMPLE
16	BAR		12	D6	15			15			1.8		×			COMPARATIVE EXAMPLE
17	CURTAIN	10	12	D8	15			15			2.1		○			EXAMPLE
18	CURTAIN	5	12	D1	15			15			0.5		○			COMPARATIVE EXAMPLE
19	CURTAIN	5	12	D2	15			15			0.8		○			COMPARATIVE EXAMPLE
20	CURTAIN	5	12	D3	15			15			1.2		○			COMPARATIVE EXAMPLE
21	CURTAIN	5	12	D4	15			15			2.3		○			EXAMPLE
22	CURTAIN	5	12	D5	15			15			4.0		○			EXAMPLE
23	CURTAIN	5	12	D6	10	D3	5	15			6.0		○			EXAMPLE
24	CURTAIN	10 5	12	D7	15			15			1.5		○			COMPARATIVE EXAMPLE
25	CURTAIN	5	12	D9	15			15			1.4		×			COMPARATIVE EXAMPLE

(continued)

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
26	CURTAIN	5	12	D10	15			15			1.8		×			COMPARATIVE EXAMPLE
27	CURTAIN	5	12					0	D11	3	1.4		○			COMPARATIVE EXAMPLE
28	CURTAIN	5	12					0	D11	15	2.3		○			EXAMPLE
29	CURTAIN	5	12					0	D11	20	2.3		○			EXAMPLE
30	CURTAIN	5	12					0	D12	0.5						COMPARATIVE EXAMPLE
31	CURTAIN	5	12					0	D12	2						EXAMPLE
32	CURTAIN	5	12					0	D12	4						EXAMPLE
33	BAR	5	12	D4	15			15			1.9		×			COMPARATIVE EXAMPLE
34	CURTAIN	15	12	D1	15			15			0.1		○			COMPARATIVE EXAMPLE
35	CURTAIN	15	12	D2	15			15			0.3		○			COMPARATIVE EXAMPLE
36	CURTAIN	15	12	D3	15			15			0.4		○			COMPARATIVE EXAMPLE

(continued)

No														REAR SURFACE COATING		REMARKS
	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)								
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)		TYPE	COVERAGE RATIO (%)						
37	CURTAIN	15	12	D4	15			15			0.8		○			COMPARATIVE EXAMPLE
38	CURTAIN	15	12	D5	15			15			1.3		○			COMPARATIVE EXAMPLE

[Table 5-2]

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
39	CURTAIN	15	12	D6	10	D3	5	15			2.1		○			EXAMPLE
40	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
41	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
42	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
43	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
44	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
45	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
46	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
47	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
48	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
49	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
50	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
51	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
52	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
53	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE

(continued)

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
54	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
55	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
56	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
57	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
58	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
59	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
60	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
61	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
62	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
63	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
64	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
65	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
66	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
67	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
68	CURTAIN	10	12	D6	15			15			3.2		○			COMPARATIVE EXAMPLE
69	CURTAIN	10	12	D6	15			15			3.2		○	SAME AS NO 1	SAME AS NO 1	EXAMPLE
70	CURTAIN	10	12	D6	15			15			3.2		○	SAME AS NO 2	SAME AS NO 1	EXAMPLE

(continued)

No	PAINTING METHOD	FILM THICKNESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICKNESS	MAXIMUM FILM THICKNESS / MINIMUM FILM THICKNESS	RESIN PARTICLE COVERAGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)				RUST PREVENTIVE PAINT FILM	OUTERMOST LAYER PAINT FILM	
				TYPE	COVERAGE RATIO (%)	TYPE	COVERAGE RATIO (%)									
71	CURTAIN	10	12	D6	15			15			3.2		○	NO COATING	NO COATING	EXAMPLE
72	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
73	CURTAIN	10	12	D6	15			15			3.2		○			EXAMPLE
74	CURTAIN	10	24	D8	15			15			2.1		○			EXAMPLE
75	CURTAIN	10	48	D8	15			15			2.1		×			EXAMPLE

[Table 5-3]

No	PAINTING METHOD	FILM THICK-NESS (μm)	HEATING TIME (s)	RESIN PARTICLE					AGGREGATE OR CURING CATALYST		PARTICLE DIAMETER / FILM THICK-NESS	Maximum FILM THICK-NESS / MINIMUM FILM THICK-NESS	RESIN PARTICLE COVER-AGE	REAR SURFACE COATING		REMARKS
				RESIN PARTICLE 1		RESIN PARTICLE 2		TOTAL COVER-AGE RATIO (%)						RUST PREVEN-TIVE PAINT FILM	OUTER-MOST LAYER PAINT FILM	
				TYPE	COVER-AGE RATIO (%)	TYPE	COVER-AGE RATIO (%)		TYPE	COVER-AGE RATIO (%)						
76	CURTAIN	12	12	D6	5			5			2.5	4	○			EXAMPLE
77	CURTAIN	8	12	D6	15			15			3.8	8	O			EXAMPLE
78	CURTAIN	12	12	D6	15			15			2.5	5	○			EXAMPLE
79	CURTAIN	8	12	D6	20			20			3.8	10	O			EXAMPLE
80	CURTAIN	12	12	D6	20			20			2.5	7	○			EXAMPLE
81	CURTAIN	20	12	D13	15			15			2.5	6	O			EXAMPLE
82	CURTAIN	20	12	D13	15			20			2.5	9	○			EXAMPLE
83	CURTAIN	20	12	D13	15			25			2.5	12	O			EXAMPLE
84	CURTAIN	15	12	D13	15			20			3.3	17	○			EXAMPLE
85	CURTAIN	13	12	D13	15			20			3.8	21	○			EXAMPLE
86	CURTAIN	25	12	D14	15			20			4.0	23	○			EXAMPLE
87	CURTAIN	20	12	D13	15			15			2.5	6	O			EXAMPLE
88	CURTAIN	20	12	D13	15			20			2.5	9	○			EXAMPLE
89	CURTAIN	20	12	D13	15			25			2.5	12	○			EXAMPLE
90	CURTAIN	15	12	D13	15			20			3.3	17	○			EXAMPLE
91	CURTAIN	13	12	D13	15			20			3.8	21	○			EXAMPLE
92	CURTAIN	20	12	D1	50			50			0.1	1.2	○			EXAMPLE
93	CURTAIN	20	12	D2	50			50			0.2	1.3	O			EXAMPLE
94	CURTAIN	20	12	D3	50			50			0.3	1.4	○			EXAMPLE

[Table 6-1]

No	EVALUATION						REMARKS
	GLOSSINESS	CORROSION RESISTANCE		FLAW RESISTANCE	ROUGHNESS	PARTICLE FALL-OFF	
		CORROSION RESISTANCE 1	CORROSION RESISTANCE 2				
1	10	4		4		O	EXAMPLE
2	60	4		2	×		COMPARATIVE EXAMPLE
3	40	4		2		○	COMPARATIVE EXAMPLE
4	19	4		4		O	EXAMPLE
5	18	4		4		○	EXAMPLE
6	15	4		4		O	EXAMPLE
7	8	4		4		○	EXAMPLE
8	7	4		4		○	EXAMPLE
9	5	4		3		○	EXAMPLE
10	60	5		2		○	COMPARATIVE EXAMPLE
11	55	5		2		○	COMPARATIVE EXAMPLE
12	53	5		2		○	COMPARATIVE EXAMPLE
13	45	4		2		○	COMPARATIVE EXAMPLE
14	20	4		4		○	EXAMPLE
15	10	4		4		O	EXAMPLE
16	40	2		2		○	COMPARATIVE EXAMPLE
17	18	5		4		○	EXAMPLE
18	45	4		2		○	COMPARATIVE EXAMPLE
19	40	3		2		○	COMPARATIVE EXAMPLE
20	38	3		2		○	COMPARATIVE EXAMPLE
21	15	3		4		O	EXAMPLE
22	6	3		4		×	EXAMPLE
23	5	3		4		○	EXAMPLE
24	30	3		2		○	COMPARATIVE EXAMPLE

(continued)

No	EVALUATION						REMARKS
	GLOSSINESS	CORROSION RESISTANCE		FLAW RESISTANCE	ROUGHNESS	PARTICLE FALL-OFF	
		CORROSION RESISTANCE 1	CORROSION RESISTANCE 2				
25	35	3		2		○	COMPARATIVE EXAMPLE
26	25	3		2		○	COMPARATIVE EXAMPLE
27	40	3		2	×		COMPARATIVE EXAMPLE
28	16	3		3	○		EXAMPLE
29	13	3		3	○		EXAMPLE
30	50	3		2	×		COMPARATIVE EXAMPLE
31	10	3		3	○		EXAMPLE
32	9	3		3	○		EXAMPLE
33	25	2		2		○	COMPARATIVE EXAMPLE
34	60	5		2		○	COMPARATIVE EXAMPLE
35	60	5		2		○	COMPARATIVE EXAMPLE
36	56	5		2		○	COMPARATIVE EXAMPLE
37	50	5		2		○	COMPARATIVE EXAMPLE
38	38	5		2		○	COMPARATIVE EXAMPLE

[Table 6-2]

No	EVALUATION						REMARKS
	GLOSSINESS	CORROSION RESISTANCE		FLAW RESISTANCE	ROUGHNESS	PARTICLE FALL-OFF	
		CORROSION RESISTANCE 1	CORROSION RESISTANCE 2				
39	18	5		4		○	EXAMPLE
40	10	2		4		○	COMPARATIVE EXAMPLE
41	10	2		4		○	COMPARATIVE EXAMPLE
42	10	3		4		○	EXAMPLE
43	10	3		4		○	EXAMPLE
44	10	4		4		○	EXAMPLE
45	10	4		4		○	EXAMPLE
46	10	4		4		○	EXAMPLE
47	10	2		4		○	COMPARATIVE EXAMPLE
48	10	2		4		○	COMPARATIVE EXAMPLE
49	10	2		4		○	COMPARATIVE EXAMPLE
50	10	3		4		○	EXAMPLE
51	10	4		4		○	EXAMPLE
52	10	4		4		○	EXAMPLE
53	10	4		3		○	EXAMPLE
54	10	4		3		○	EXAMPLE
55	10	2		2		○	COMPARATIVE EXAMPLE
56	10	4		4		○	EXAMPLE
57	10	4		4		○	EXAMPLE
58	10	4		4		○	EXAMPLE
59	10	3		4		○	EXAMPLE
60	10	3		4		○	EXAMPLE
61	10	3		4		○	EXAMPLE
62	10	3		4		○	EXAMPLE

(continued)

No	EVALUATION						REMARKS
	GLOSSINESS	CORROSION RESISTANCE		FLAW RESISTANCE	ROUGHNESS	PARTICLE FALL-OFF	
		CORROSION RESISTANCE 1	CORROSION RESISTANCE 2				
63	10	3		4		○	EXAMPLE
64	10	3		4		○	EXAMPLE
65	10	4		4		○	EXAMPLE
66	10	4		4		○	EXAMPLE
67	10	5		4		○	EXAMPLE
68	10	1		4		○	COMPARATIVE EXAMPLE
69	10	4	2	4		○	EXAMPLE
70	10	4	1	4		○	EXAMPLE
71	10	4	1	4		○	EXAMPLE
72	9	4		4		○	EXAMPLE
73	8	4		4		○	EXAMPLE
74	18	4		4		○	EXAMPLE
75	18	3		4		○	EXAMPLE

[Table 6-3]

No	EVALUATION						REMARKS
	GLOSSINESS	CORROSION RESISTANCE		FLAW RESISTANCE	ROUGHNESS	PARTICLE FALL-OFF	
		CORROSION RESISTANCE 1	CORROSION RESISTANCE 2				
76	20	4		4		○	EXAMPLE
77	7	3		4		○	EXAMPLE
78	9	4		4		○	EXAMPLE
79	5	3		4		○	EXAMPLE
80	8	4		4		○	EXAMPLE
81	8	4		4		○	EXAMPLE
82	7	4		4		○	EXAMPLE
83	5	3		4		○	EXAMPLE
84	5	3		4		○	EXAMPLE
85	5	3		3		×	EXAMPLE
86	5	3		3		×	EXAMPLE
87	8	5		4		○	EXAMPLE
88	7	5		4		○	EXAMPLE
89	5	5		4		○	EXAMPLE
90	5	5		4		○	EXAMPLE
91	5	5		3		×	EXAMPLE
92	20	3		3		×	EXAMPLE
93	18	3		3		×	EXAMPLE
94	17	3		3		×	EXAMPLE

[0100] As is clear from Table 4-1 to Table 6-3 above, the sample materials corresponding to the examples of the present invention are shown to be capable of achieving both the matte appearance with excellent low glossiness and the high corrosion resistance. Further, the sample materials are shown to secondarily exhibit high flaw resistance. Further, the sample materials corresponding to the configurations satisfying the preferred aspect of the present invention are shown to exhibit the effect of suppressing the fall-off of the particles. On the other hand, the sample materials corresponding to the comparative examples of the present invention were unacceptable in at least either the low glossiness or the corrosion resistance.

[0101] No. 2 contained no resin particle in the outermost layer paint film layer, and No. 3 contained resin particles but was low in percentage thereof. Besides, No. 27 contained no resin particle in the outermost layer paint film layer, and contained the aggregate but was low in percentage thereof. Besides, No. 30 contained no resin particle in the outermost layer paint film layer, and contained the curing catalyst but was low in percentage thereof. Therefore, it is considered that the glossiness was outside of the range and the desired design could not be realized.

[0102] Nos. 10 to 13, 16, 18 to 20, 24 to 26, and 33 to 38 were less than twice the disclosure of this application in the ratio (particle diameter/film thickness) between the average particle diameter φ_{10} and the average film thickness T. Therefore, it is considered that the glossiness was outside of the range and the desired design could not be realized.

[0103] Nos. 40 and 41 were less than 5 μm in the film thickness of the rust preventive paint film (see Table 4-1), and therefore it is considered that the effect of suppressing the corrosion against the corrosion factor possibly intruding through the interface between the thin film portion or the particle 101 and the binder resin 103 was not sufficient. Therefore, it is considered that the desired corrosion resistance could not be obtained. Besides, No. 47 was more than 15 μm in the film thickness of the rust preventive paint film, and therefore it is considered that the paint defect occurred. Therefore, it is considered that the desired corrosion resistance could not be obtained.

[0104] Nos. 48 and 49 were less than 30% in the coverage ratio of the rust preventive pigment (see Table 4-1), and therefore it is considered that the effect of suppressing the corrosion against the corrosion factor possibly intruding through the interface between the thin film portion or the particle 101 and the binder resin 103 was not sufficient. Therefore, it is considered that the desired corrosion resistance could not be obtained. Besides, No. 55 was more than 60% in the coverage ratio of the rust preventive pigment (see Table 4-1), and therefore it is considered that the adhesiveness between the rust preventive paint film layer 20 and the steel sheet 10, particularly, the adhesiveness at the worked portion was not sufficient. Therefore, it is considered that the desired corrosion resistance could not be obtained.

[0105] No. 68 was not provided with the plating layer on the surface of the steel sheet 10 (using the metal sheet A5), and therefore it is considered that the desired corrosion resistance could not be obtained.

[0106] Preferred embodiments of the present invention have been explained above in detail with reference to the attached drawings, but the present invention is not limited to the embodiments. It should be understood that various changes and modifications are readily apparent to those skilled in the art who have the common general knowledge in the technical field to which the present invention pertains, within the scope of the technical spirit as set forth in claims, and they should also be covered by the technical scope of the present invention.

[0107] The embodiments disclosed herein are examples in all respects and should not be considered to be restrictive. Various omissions, substitutions, and changes may be made in the embodiments without departing from the scope and the spirit of the attached claims and a later-explained technical scope of the present invention. For example, configuration requirements of the above embodiments can be arbitrarily combined within a range that does not impair the effects thereof. Further, from the arbitrary combination, the operations and effects about the configuration requirements relating to the combination can be naturally obtained, and other operations and other effects apparent to those skilled in the art are obtained from the description herein.

[0108] Besides, the effects explained herein are merely explanatory or illustrative in all respects and not restrictive. In other words, the technique relating to the present invention can offer other effects apparent to those skilled in the art from the description herein in addition to or in place of the above effects.

[0109] Note that the following configurations also belong to the technical scope of the present invention.

[1] A painted steel sheet including
two or more paint film layers including a rust preventive paint film layer on at least one side of a steel sheet having a Zn-containing plating layer, wherein:

a 60-degree specular glossiness Gs (60°) specified in JIS Z 8741:1997 of the paint film layer on at least one face of the steel sheet is 20% or less;
an average film thickness of the rust preventive paint film layer is 5 μm or more and 15 μm or less;
the rust preventive paint film layer contains a binder resin, a cross-linking agent, and a rust preventive pigment; and
in a cross section obtained by cutting the paint film layer in a thickness direction at an arbitrary position, a coverage ratio of the rust preventive pigment to a total area of the rust preventive paint film layer is 30% or more and 60% or

less in terms of area ratio.

[2] The painted steel sheet according to the above [1], wherein
the rust preventive pigment contains at least one or more of Si, P, Mg, and V.

[3] The painted steel sheet according to the above [2], wherein
the Si contains any one or more of calcium ion-exchanged silica and magnesium ion-exchanged silica, the P contains any one or more of zinc phosphate, magnesium dihydrogen phosphate, and aluminium dihydrogen triphosphate, and the Mg contains any one or more of magnesium dihydrogen phosphate, magnesium oxide, and magnesium hydroxide.

[4] The painted steel sheet according to any one of the above [1] to [3], wherein:

on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, the two or more paint film layers have the rust preventive paint film layer at a lower layer and have a colored paint film layer at an outermost layer located on a farthest side from the steel sheet, and the colored paint film layer contains a resin particle, and a binder resin, a cross-linking agent, and a color pigment as a film-forming component; and
in the cross section, an average particle diameter of the resin particle is two times or more and five times or less an average film thickness at a portion not having the resin particle of the outermost layer paint film layer.
Where the average particle diameter is a value obtained by measuring, in one observation visual field region in the cross section, circle-equivalent diameters of the resin particles existing in the observation visual field region, calculating an average value of upper two circle-equivalent diameters in descending order of the circle-equivalent diameters, and further averaging the averaged values similarly obtained for the observation visual field regions at ten arbitrary locations, by a number of fields of view.

[5] The painted steel sheet according to the above [4], wherein
the coverage ratio of the resin particles to a total area of the outermost layer paint film layer is 5% or more and 30% or less in terms of area ratio.

[6] The painted steel sheet according to the above [4] or [5], wherein
in the cross section, a projecting portion of the resin particle projecting from a position on a surface at the portion not containing the resin particle of the outermost layer paint film layer is covered, at half or more of a length along an outer peripheral portion of the projecting portion, with the film-forming component having a thickness of 0.5 μm or more.

[7] The painted steel sheet according to any one of the above [4] to [6], wherein
the resin particle is a resin particle made of an acrylic resin.

[8] The painted steel sheet according to any one of the above [4] to [7], wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.

[9] The painted steel sheet according to any one of the above [1] to [8] having a characteristic selected from any one or two of a surface roughness of the steel sheet being 2 μm or more in Ra on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, and the paint film layer containing 15% or more of an aggregate composed of a pigment containing silica.

EXPLANATION OF CODES

[0110]

1	painted steel sheet
10	steel sheet
20	rust preventive paint film layer
30	outermost paint film layer
101	particle
103	binder resin

Claims

1. A painted steel sheet comprising
two or more paint film layers including a rust preventive paint film layer on at least one side of a steel sheet having a Zn-containing plating layer, wherein:

a 60-degree specular glossiness Gs (60°) specified in JIS Z 8741:1997 of the paint film layer on at least one face of the steel sheet is 20% or less;

an average film thickness of the rust preventive paint film layer is 5 μm or more and 15 μm or less;
the rust preventive paint film layer contains a binder resin, a cross-linking agent, and a rust preventive pigment; and
in a cross section obtained by cutting the paint film layer in a thickness direction at an arbitrary position, a coverage ratio of the rust preventive pigment to a total area of the rust preventive paint film layer is 30% or more and 60% or less in terms of area ratio.

2. The painted steel sheet according to claim 1, wherein
the rust preventive pigment contains at least one or more of Si, P, Mg, and V.

3. The painted steel sheet according to claim 2, wherein
the Si contains any one or more of calcium ion-exchanged silica and magnesium ion-exchanged silica, the P contains any one or more of zinc phosphate, magnesium dihydrogen phosphate, and aluminium dihydrogen triphosphate, and the Mg contains any one or more of magnesium dihydrogen phosphate, magnesium oxide, and magnesium hydroxide.

4. The painted steel sheet according to claim 1, wherein:

on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, the two or more paint film layers have the rust preventive paint film layer at a lower layer and have a colored paint film layer at an outermost layer located on a farthest side from the steel sheet, and the colored paint film layer contains a resin particle, and a binder resin, a cross-linking agent, and a color pigment as a film-forming component; and
in the cross section, an average particle diameter of the resin particle is two times or more and five times or less an average film thickness at a portion not having the resin particle of the colored paint film layer.
Where the average particle diameter is a value obtained by measuring, in one observation visual field region in the cross section, circle-equivalent diameters of the resin particles existing in the observation visual field region, calculating an average value of upper two circle-equivalent diameters in descending order of the circle-equivalent diameters, and further averaging the averaged values similarly obtained for the observation visual field regions at ten arbitrary locations, by a number of fields of view.

5. The painted steel sheet according to claim 4, wherein
the coverage ratio of the resin particles to a total area of the colored paint film layer is 5% or more and 30% or less in terms of area ratio.

6. The painted steel sheet according to claim 4, wherein
in the cross section, a projecting portion of the resin particle projecting from a position on a surface at the portion not containing the resin particle of the colored paint film layer is covered, at half or more of a length along an outer peripheral portion of the projecting portion, with the film-forming component having a thickness of 0.5 μm or more.

7. The painted steel sheet according to any one of claims 4 to 6, wherein
the resin particle is a resin particle made of an acrylic resin.

8. The painted steel sheet according to any one of claims 4 to 6, wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.

9. The painted steel sheet according to claim 7, wherein
the binder resin is a binder resin made of an acrylic resin or a polyester resin.

10. The painted steel sheet according to claim 1 or 2, having a characteristic selected from any one or two of a surface roughness of the steel sheet being 2 μm or more in Ra on the face of the steel sheet where the 60-degree specular glossiness Gs (60°) is 20% or less, and the paint film layer containing 15% or more of an aggregate composed of a pigment containing silica.

FIG.1A

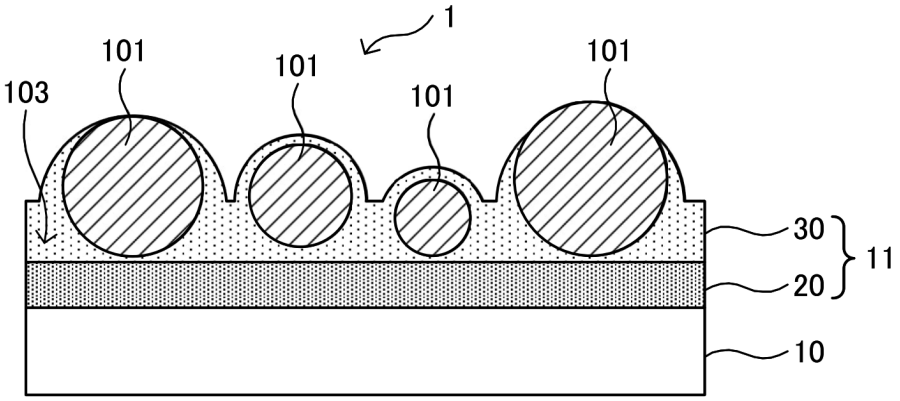

1
101
101
101
101
103
30
20
11
10

FIG.1B

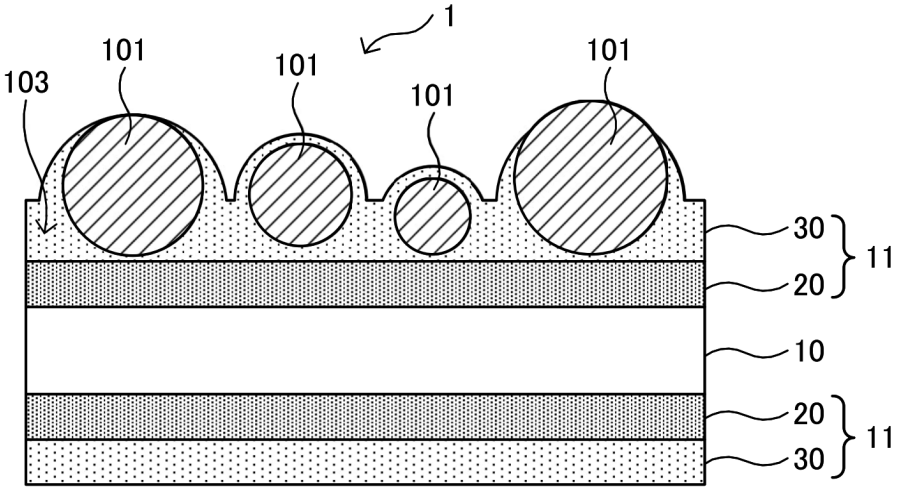

1
101
101
101
101
103
30
20
11
10
20
11
30

FIG.1C

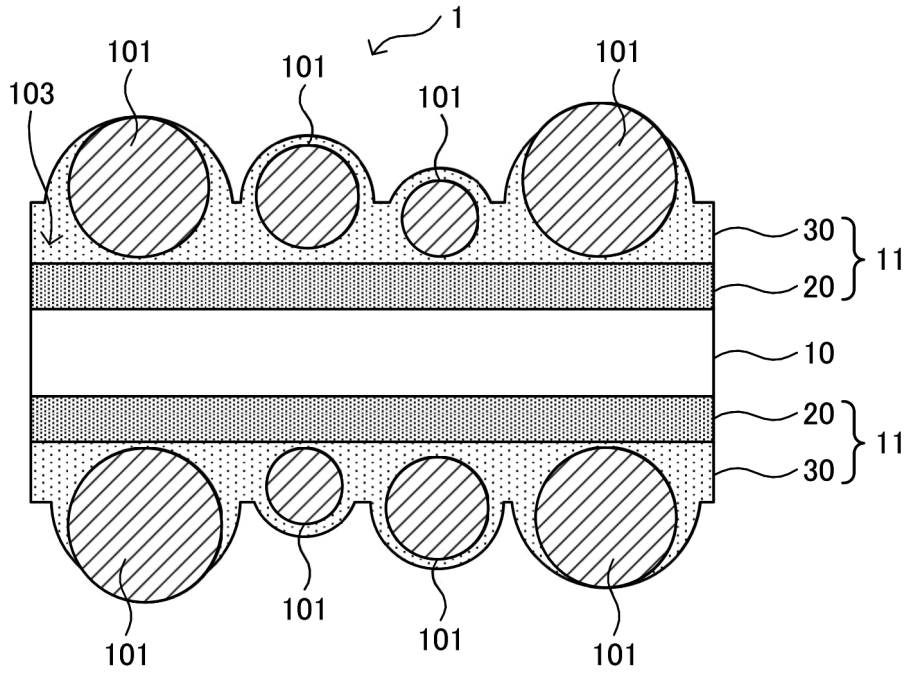


FIG.2A

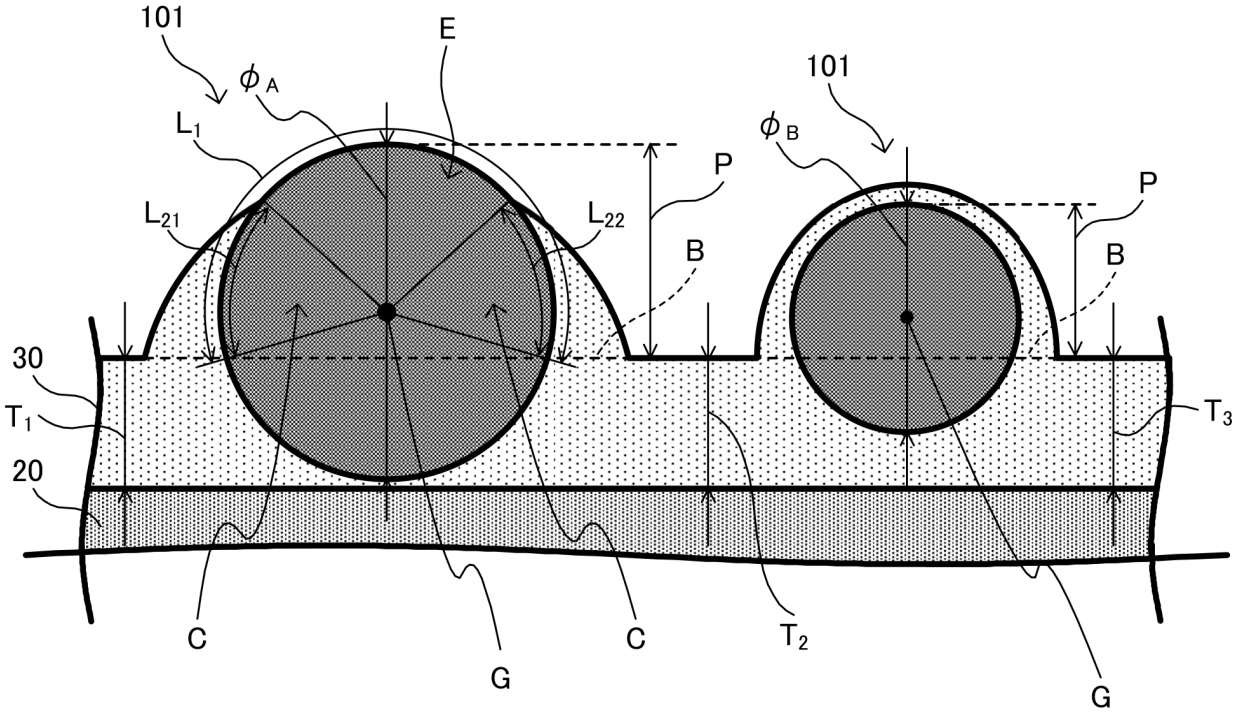

101
E
ϕ_A
L_1
L_{21}
L_{22}
P
B
101
ϕ_B
P
B
30
T_1
20
T_3
C
G
C
T_2
G

FIG.2B

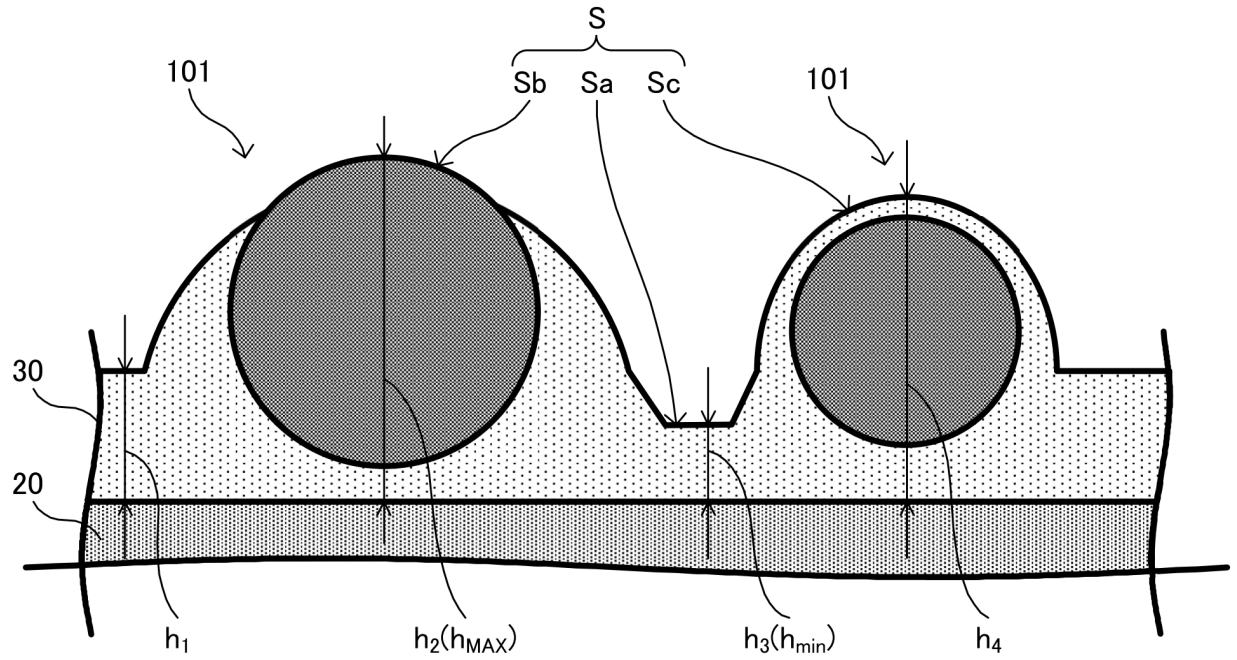

S
101
Sb
Sa
Sc
101
30
20
h_1
$h_2(h_{MAX})$
$h_3(h_{min})$
h_4

FIG.3A

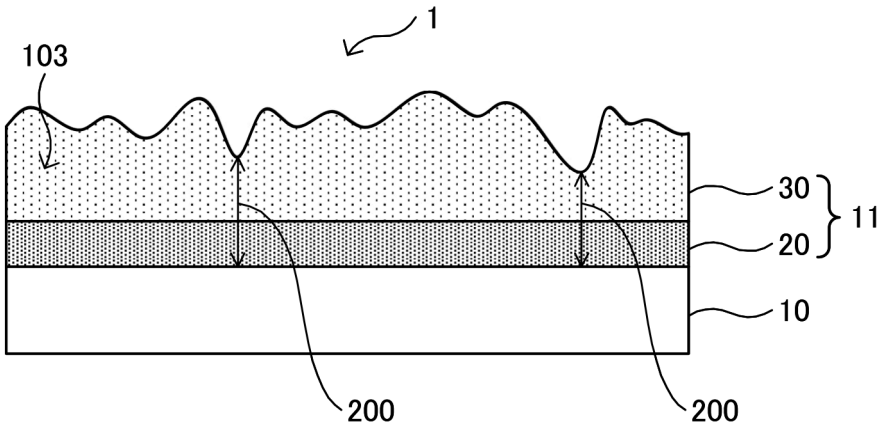
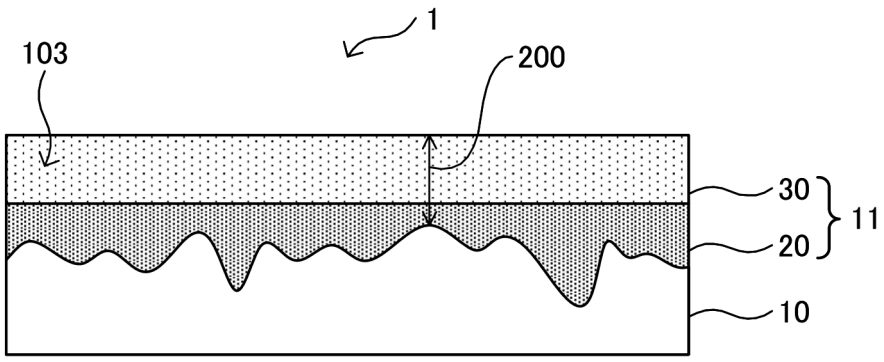


FIG.3B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/024107

A. CLASSIFICATION OF SUBJECT MATTER

B32B 15/08(2006.01)i; ***B32B 15/18***(2006.01)i; ***C23C 26/00***(2006.01)i
FI: B32B15/08 G; B32B15/18; C23C26/00 A

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B32B15/08; C23C26/00; B05D5/06; B05D7/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2024
Registered utility model specifications of Japan 1996-2024
Published registered utility model applications of Japan 1994-2024

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-119360 A (NIPPON FINE COATINGS INC.) 04 June 2009 (2009-06-04) claims, paragraphs [0001], [0012]-[0062]	1-3, 10
Y		4-9
X	JP 2020-142373 A (NIPPON STEEL NISSHIN CO., LTD.) 10 September 2020 (2020-09-10) claims, paragraphs [0085]-[0115]	1-3, 10
X	WO 2012/133671 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 04 October 2012 (2012-10-04) claims, paragraphs [0254]-[0257], [0306]-[0343]	1-3, 10
Y	JP 2004-209974 A (NIPPON STEEL CORPORATION) 29 July 2004 (2004-07-29) claims, paragraphs [0001], [0014]-[0058], fig. 1-4	4-9
A	JP 2000-192254 A (SUMITOMO METAL INDUSTRIES, LTD.) 11 July 2000 (2000-07-11) entire text	1-10

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 September 2024	**24 September 2024**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/024107

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-183928 A (NIPPON KOKAN KK) 16 July 1996 (1996-07-16) entire text	1-10
A	JP 2020-157246 A (NIPPON STEEL NISSHIN CO., LTD.) 01 October 2020 (2020-10-01) entire text	1-10

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/024107

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2009-119360 A	04 June 2009	(Family: none)	
JP 2020-142373 A	10 September 2020	(Family: none)	
WO 2012/133671 A1	04 October 2012	US 2014/0023879 A1 claims, paragraphs [0404]-[0441], tables 4-5, 21-32 CA 2831402 A KR 10-2013-0114275 A CN 103459677 A MX 2013011084 A JP 2013-108183 A	
JP 2004-209974 A	29 July 2004	(Family: none)	
JP 2000-192254 A	11 July 2000	(Family: none)	
JP 8-183928 A	16 July 1996	(Family: none)	
JP 2020-157246 A	01 October 2020	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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