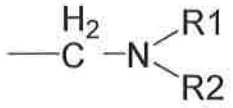
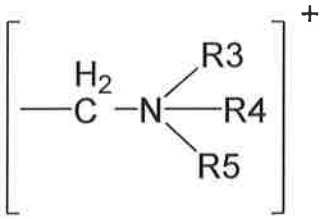
average number of substituents of Z groups per benzene ring is 0.2 to 1.0. The average number of substituents of Z groups can be found from an integration ratio by ^{1}H-NMR.

[0067]

[Chem. 3]



(3)



(4)

[0068]

R1, R2, R3, R4, and R5 in General Formula (3) and General Formula (4) above independently represent a hydrogen atom, an alkyl group having 1 to 10 carbon atoms, or a hydroxyalkyl group having 1 to 10 carbon atoms, and A^- represents a hydroxide ion or an oxoacid (for example, nitrate, sulfate, phosphate, carbonate, carboxylate, or the like) ion.

[0069]

For the water-based surface treatment agent, it is preferable that an anion that volatilizes during drying and film production be used as a counter-anion to each of the cationic polyurethane resin and the cationic phenolic resin. As the anion that volatilizes during drying and film production, specifically, a formate ion or an acetate ion is preferable.

[0070]

<Silane coupling agent (C)>

The silane coupling agent (C) is turned into a silanol by hydrolysis in the step of drying (baking) a wet coating film formed by applying the water-based surface treatment agent, and forms a siloxane-type dry coating film that is three-dimensionally crosslinked by siloxane bonds.

coating film formed by applying the water-based surface treatment agent, and is precipitated as a titanium compound in the dry coating film 3. Even when an acetylacetonate and acetylacetone derived from the acetylacetone complex of titanium (D) exist in the dry coating film 3, these have weak ionicity, and therefore do not adversely influence the likelihood of water condensation whitening. Examples of the acetylacetone complex of titanium (D) include titanium diisopropoxide bis(acetylacetonate), titanium tetrakis(acetylacetonate), and the like.

[0075]

<Vanadium compound (E)>

As the vanadium compound (E), a compound not containing a strong electrolyte or a salt with a volatile acid is preferably used. As the vanadium compound (E) not containing a strong electrolyte, vanadium pentoxide, metavanadic acid and a salt thereof (for example, ammonium metavanadate), vanadium trioxide, vanadium dioxide, vanadium oxyacetylacetonate, vanadium acetylacetonate, or the like is given. As the salt with a volatile acid, vanadium acetate or the like is given. Among the vanadium compounds (E) mentioned above, an acetylacetone complex of vanadium such as vanadium acetylacetonate or vanadium oxyacetylacetonate is used particularly preferably in view of the effect of improving corrosion resistance.

[0076]

<Olefin-based wax (F)>

The olefin-based wax (F) is contained in the water-based surface treatment agent as necessary, and may not be contained. The olefin-based wax (F) is preferably contained in the water-based surface treatment agent in order to impart lubricity to the dry coating film 3.

Examples of the olefin-based wax (F) include polyethylene wax, polyethylene oxide wax, polypropylene oxide wax, and the like.

[0077]

The resin particle made of the olefin-based wax (F) is preferably surface-modified with a silane coupling agent (I). In the case where the olefin-based wax (F) is one surface-modified with the silane coupling agent (I), the wettability of the olefin-based wax (F) in the water-based surface treatment agent is increased. Thus,

acid component (G), each component of such a water-based surface treatment agent is not stabilized, and consequently the first component cannot disperse uniformly or finely in the formed dry coating film.

[0082]

Examples of the acetic acid component (G) include acetic acid, ammonium acetate, potassium acetate, sodium acetate, and the like. Acetic acid is particularly preferable in view of the chemical agent stability of the water-based surface treatment agent. Further, the boiling point of acetic acid is 118°C, which is a lower boiling point among the boiling points of organic acids having buffer action, and acetic acid is less likely to remain in the dry coating film 3. Thus, acetic acid is suitable as the acetic acid component (G) that is put in the water-based surface treatment agent.

[0083]

<Phosphoric acid component (H)>

Examples of the phosphoric acid component (H) include inorganic phosphate compounds such as phosphoric acid, ammonium phosphate, potassium phosphate, sodium phosphate, and monosodium dihydrogen phosphate. Among these, in particular, phosphoric acid is preferably used as the phosphoric acid component (H) in view of the effect of improving stacking whitening resistance and filament tape resistance and an effect in which a dry coating film 3 in which the first component 31 and the second component 32 are arranged more uniformly is obtained.

[0084]

The phosphoric acid component (H) contained in the water-based surface treatment agent reacts with the plating layer 2, and produces a zinc phosphate dry coating film on the surface of the plating layer 2. The zinc phosphate dry coating film suppresses the dissolving-out of zinc from the plating layer 2, and suppresses the occurrence of white rust. Further, the phosphoric acid component (H) reduces the amount of the acetic acid component (G) remaining in the dry coating film 3. As a result, an event in which an adhesive layer of a filament tape that is used to temporarily stick an end portion of a coil formed of the surface-treated steel sheet 10 is attacked by the acetic acid component (G) can be prevented, and the

adhesiveness reduction of the filament tape can be suppressed. Further, a reduction in water condensation whitening resistance due to the acetic acid component (G) remaining in the dry coating film 3 can be prevented.

[0085]

As the phosphoric acid component (H), an inorganic phosphate is preferable in view of stability in a chemical agent.

[0086]

Preferred blending ratios of the components contained in the water-based surface treatment agent used in the present embodiment are as follows.

(1) The ratio (NC)/(NV) of the mass of the silane coupling agent (C) on a SiO_2 basis to the mass of the solid content (V) of the water-based surface treatment agent is 0.10 to 0.40

(2) The ratio (ND)/(NV) of the mass (ND) of the acetylacetone complex of titanium (D) on a Ti basis to the mass of the solid content (V) is 0.017 to 0.024

(3) The ratio (NE)/(NV) of the mass (NE) of the vanadium compound (E) on a V basis to the mass of the solid content (V) is 0.007 to 0.009

(4) The ratio (NF)/(NV) of the mass of the olefin-based wax (F) to the mass of the solid content (V) is 0.035 to 0.060

(5) The ratio (NG)/(NV) of the mass of the acetic acid component (G) to the mass of the solid content (V) is 0.04 to 0.14

(6) The ratio (NH)/(NV) of the mass of the phosphoric acid component (H) to the mass of the solid content (V) is 0.025 to 0.075

(7) The ratio (ND)/(NE) of the mass of the acetylacetone complex of titanium (D) on a Ti basis to the mass of the vanadium compound (E) on a V basis is 2.1 to 2.9

(8) The ratio (NH)/(NG) of the mass of the phosphoric acid component (H) to the mass of the acetic acid component (G) is 0.25 to 1.1

[0087]

<(NC)/(NV)>

The ratio (NC)/(NV) of the mass of the silane coupling agent (C) on a SiO_2 basis to the mass of the solid content (V) of the water-based surface treatment agent is preferably 0.10 to 0.40, and more preferably 0.16 to 0.19. When (NC)/(NV) is

or equal to 2.1, a dry coating film 3 in which the effect of improving corrosion resistance based on the titanium compound (D) is obtained sufficiently is obtained. When (ND)/(NE) is less than or equal to 2.9, a dry coating film 3 in which the effect of improving corrosion resistance based on the vanadium compound (E) is obtained sufficiently is obtained. When (ND)/(NE) is 2.1 to 2.9, corrosion in various corrosion environments can be suppressed by the synergy of Ti and V, and a dry coating film 3 having more excellent corrosion resistance is obtained.

[0094]

<(NH)/(NG)>

The ratio (NH)/(NG) of the mass of the phosphoric acid component (H) to the mass of the acetic acid component (G) is 0.25 to 1.1, preferably 0.30 to 1.0, and more preferably 0.35 to 0.9. When (NH)/(NG) is 0.25 to 1.1, the effect of improving the stability of the water-based surface treatment agent based on the acetic acid component (G) is obtained sufficiently, and the reduction in water condensation whitening resistance and the reduction in the adhesiveness of a filament tape due to the remaining of the acetic acid component (G) in the dry coating film 3 can be suppressed.

[0095]

The water-based surface treatment agent can be prepared by dissolving or dispersing the components mentioned above in a water-based solvent at the blending ratios mentioned above. Each component is adjusted to a prescribed ratio to the mass of the nonvolatile content (the solid content (V)) excluding the solvent and the volatile components (the mass of the dry coating film) so as to be at a prescribed ratio in the dry coating film 3.

The water-based solvent used for the water-based surface treatment agent may be water alone. For the purpose of improving the dryability of a wet coating film formed by applying the water-based surface treatment agent, etc., a water-soluble organic solvent not containing a strong electrolyte (for example, alcohols) may be put in the water-based solvent used for the water-based surface treatment agent in a contained amount of, for example, less than or equal to 30 mass% of the entire water-based solvent.

[0107]

[Phenolic resin (B)]

B1: Cationic phenolic resin

The average degree of polymerization n of a repeating unit of General Formula (2) = 5

X of General Formula (2) = $-CH_2N(CH_3)_2$

Y of General Formula (2) = H

The degree of Z-substitution of General Formula (2) = 0.5

[0108]

[Silane coupling agent (C)]

C1: 3-Aminopropyltriethoxysilane

C2: 3-Glycidoxypropyltrimethoxysilane

C3: 3-Mercaptopropyltrimethoxysilane

[0109]

[Acetylacetone complex of titanium (D)]

D1: Titanium diisopropoxide bis(acetylacetonate)

D2: Titanium tetrakis(acetylacetonate)

D3: Titanium hydrofluoric acid (a component containing fluoride ions)

[Vanadium compound (E)]

E1: Vanadium acetylacetonate

[0110]

[Olefin-based wax (F)]

F1: Olefin-based wax with an average particle size of 0.05 μm

F2: Olefin-based wax with an average particle size of 0.05 μm, surface-modified with a silane coupling agent (3-glycidoxypropyltrimethoxysilane). The contained amount of the silane coupling agent contained in the olefin-based wax [mass of silane coupling agent/mass of olefin-based wax] = 0.030

[0111]

[Acetic acid component (G)]

G1: Acetic acid

[Phosphoric acid component (H)]