[0012] By the present disclosure, a metalic coated steel product which is less likely to experience LME and blowhole formation and is likely to exhibit an improved corrosion resistance at welding heat affected zones can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1 shows an SEM backscattered electron image illustrating a conventional Zn-Al-Mg plating layer (Zn: 11%; Al: 3%; Mg: 0.2%; Si).

Fig. 2 shows an SEM backscattered electron image illustrating one example of the plating layer of the present disclosure (the plating layer No. 18A in Example A).

Fig. 3 shows a Zn-Al phase diagram (expressed in % by mass).

Fig. 4 shows an SEM backscattered electron image illustrating another example of the plating layer of the present disclosure (the plating layer No. 8A in Example A).

Fig. 5 shows an SEM backscattered electron image of a cross-section of a plating layer used to explain a method of identifying Al phases (α and β-phases).

Fig. 6 shows an enlarged image of the SEM backscattered electron image of Fig. 5.

Fig. 7 shows an SEM backscattered electron image of a cross-section of a plating layer to explain methods of determining the Zn-Al-$MgZn_2$ ternary eutectic structure and measuring each area fraction.

DESCRIPTION OF EMBODIMENTS

[0014] Now, one example of the present disclosure will be described below.

In the present disclosure, the "%" representation of each element in a chemical composition to indicate the content refers to the content of the element in "% by mass."

Additionally, a numerical range defined by low and high values connected each other using the term "to" refers to a range of numbers including the numerical values before and after the "to" as the lower and upper limits, respectively.

Additionally, where the term "more than" or "less than" respectively precedes a lower or higher value of the numerical values connected each other using the term "to" to define a numerical range, the numerical range refers to any range of numbers within that range but excluding either or both of the numerical values as the lower or upper limit.

Additionally, the content of each element in a composition may be represented by the amount of the element (for example, the amount of Zn, Mg, or the like) or the concentration of the element (for example, the concentration of Zn, Mg, or the like).

Additionally, the term "step" is used not only to refer to independent steps but also to refer inclusively to any step which is not clearly distinguishable from other steps as long as the expected purpose of the step is achieved.

Additionally, the term "planar portion" refers to the entire portion of the surface of a steel sheet except for a welding heat affected zone of the steel product, and the term "area around a welded zone" refers to a heat affected zone of a steel product during a welding process, excluding the welded zone itself (welded metal portion), and the term "area behind a welded zone" refers to a portion of the back surface of a steel product opposite to a welded

hot-dip plating method is approximately 95 μm, depending on specific gravity and homogeneity of a plating metal.

Since the thickness of a plating layer can be freely adjusted by changing the withdrawal rate from a plating bath and the wiping conditions, it is not particularly difficult to form a plating layer with a thickness of 2 to 95 μm.

[0028] Next, the Al-Fe alloy layer will be described.

[0029] The Al-Fe alloy layer is formed on a surface of the steel product (in particular, between the steel product and the Zn-Al-Mg alloy layer) and is a layer having a structure that contains an Al_5Fe phase as a main phase. The Al-Fe alloy layer is formed by atomic diffusion between the ground steel (a steel product) and an aluminium material in a plating bath. In cases where a hot-dip plating method is used as a preparation method, a plating layer containing Al element is prone to conversion into an Al-Fe alloy layer. Because the concentration of Al contained in the plating bath is at or above a certain concentration, a phase of Al_5Fe is most generated. However, the atomic diffusion requires much time and also causes the Fe concentration to increase at some areas near the ground steal. Thus, the Al-Fe alloy layer may partially contain small amounts of, for example, AlFe, Al_3Fe, and Al_5Fe_2 phases. Additionally, the Al-Fe alloy layer contains a small amount of Zn because the plating bath contains a certain concentration of Zn.

[0030] The level of corrosion resistance is not significantly different among the Al_5Fe, Al_3Fe, AlFe, and Al_5Fe_2 phases. The corrosion resistance as described herein refers to the corrosion resistance of the plating layer at areas not affected by welding. The Al-Fe alloy layer has a smaller than that of the plating layer and also has a lower corrosion resistance than that of the Zn-Al-Mg alloy layer, and the corrosion resistance of the whole plating layer is consequently not significantly varied even if the fractions of those phases are changed.

[0031] In cases where the plating layer contains Si, the Si may easily be incorporated particularly into the Al-Fe alloy layer to form phases of Al-Fe-Si compounds. AlFeSi phase is one of the identified compounds and isomers of the compound include, for example, α-, β-, q1-, and q2-AlFeSi phases. Thus, AlFeSi phases, such as those described above, may be detected in the Al-Fe alloy layer. An Al-Fe alloy layer containing, for example, those AlFeSi phases may also be called Al-Fe-Si alloy layer.

The Al-Fe-Si alloy layer likewise has a smaller thickness than that of the Zn-Al-Mg alloy layer and consequently has a smaller effect on the corrosion resistance of the whole plating layer.

[0032] Additionally, in cases where a various metalic precoated steel product is used as a base material for the metalic coated steel product, the structure of the Al-Fe alloy layer may vary depending on the thickness of the preplating layer. Specific examples of the varied structure include a structure where a layer of a pure metal(s) used for the preplating is left around the Al-Fe alloy layer, a structure where an alloy layer of intermetallic compound phases (such as, for example, Al_3Ni phase) is formed by combination of components of the Zn-Al-Mg alloy layer and the preplating layer, a structure where an Al-Fe alloy layer with

prevented by adding Fe to the plating bath in advance to a supersaturated concentration of around 0.5%.

[0086]

<Impurities>

Impurities refer to components contained in raw materials or contaminated during the production process, wherein the components are not intended to be incorporated. For example, atomic diffusion between the steel product (the ground steel) and materials in the plating bath may result in the plating layer containing trace amounts of components other than Fe as impurities.

[0087]

<Preferred chemical composition>

Preferably, in the chemical composition of the plating layer, the content of Al is from more than 22% to less than 35%, and the content of Mg is from more than 10% to less than 20%, and the content of Ca is from 0.3% to less than 3.0%, and the content of Si is from 0.1% to 1.0%. Additionally, the content of Ca is preferably equal to or above twice the content of Si. When the concentration of each of the elements Al, Mg, Ca and Si is within the corresponding range defined above, the above-described various intermetallic compound phases are easily generated and the effects to reduce LME and blowhole formation and to improve the corrosion resistance at welding heat affected zones are enhanced.

[0088] Additionally, the content of Al may be from more than 15% to 22%, or from more than 15% to 20%. A decreased Al concentration leads to improvement of corrosion resistance after plating.

Many of welded structural objects are coated after welding. In cases where welded zones are exposed to the outside, the areas around the welded zones are prone to red rust early, and any plating is thus preferably applied to ensure the corrosion resistance at the welded zones. When an area around a welded zone is coated by, for example, electrodeposition plating and the behavior of red rust formation starting from the welded zone is then observed, a correlation is observed between the Al concentration and the corrosion resistance after plating. In cases where a welded zone is coated, a sufficient level of corrosion resistance after plating is achieved at the welded zone even if the Al concentration is more than 22%. However, from the observation of the behavior of red rust formation starting from the area around the welded zone, the Al concentration is preferably not more than 22%, more preferably not more than 20%, in terms of preventing red rust formation from an area around a welded zone. This is assumed to be because the corrosion resistance after plating is affected by the adhesion of the metallic surface of the plating layer to a coating film and the surface preparation, which affects the adhesion to a coating film, is more effective on a plating layer having a lower Al concentration.

[0089] Next, the constituent phases of the Zn-Al-Mg alloy layer will be described.

[0090] The Zn-Al-Mg alloy layer is a layer mainly composed of two phases, namely $MgZn_2$ and Al phases. The Zn-Al-Mg alloy layer contains no or little Zn-Al-$MgZn_2$ ternary eutectic

heat affected zones because a Zn phase is easily evaporated. Thus, the content of Zn phase should also be controlled. In cases where the concentration of Zn is high, a Zn phase is easily generated; however, in cases where the area fraction of Zn phase in the Zn-Al-Mg alloy layer is not less than 10%, LME and the amount of generated blowholes are increased.

[0115] However, even in cases where the area fraction of Zn phase is not less than 10%, LME and blowhole formation can be reduced by achieving a state where Ca-Zn-Al and Ca-Zn-Al-Si intermetallic compound phases exist in the Zn-Al-Mg alloy layer, as described below.

[0116] Accordingly, the area fraction of Zn phase may be less than 25%.

However, a tendency to see a small amount of Zn phase as favorable is not changed in terms of weldability.

Thus, the area fraction of Zn phase should be preferably less than 10%, more preferably not more than 5%, and further preferably not more than 3%. However, the area fraction of Zn phase is ideally 0% and may be not less than 2% in terms of manufacture.

The final solidification portion in the plating layer (420 to 380°C) is often the Zn phase, but precipitation of a single Zn phase can be inhibited as much as possible by applying any component adjustment, element addition, and even solidification method for Zn phase reduction.

[0117] Next, the intermetallic compound phases will be described.

The presence of Ca in the plating layer may cause generation of a Ca-Zn-Al intermetallic compound phase in the Zn-Al-Mg alloy layer. This is due to the intrinsic nature of Ca to promote the generation of intermetallic compound phases with Al and Zn (such as $CaZn_2$, $CaZn_5$, $CaZn_{11}$, and Al_4Ca phases). In cases where the concentration of Ca is high, an intermetallic compound phase in which the Ca is linked to those elements is not allocated to only one of these intermetallic compound phases because Ca is very prone to segregation. The Ca-Zn-Al intermetallic compound phase is oxidized to form CaO at areas behind welded zones during welding and forms an oxide layer with excellent adhesiveness on the Al-Fe alloy layer. The formation of the oxide layer improves the corrosion resistance at the areas behind the welded zones.

[0118] In this respect, the amount and size of the Ca-Zn-Al intermetallic compound phase depend on the weldability and the corrosion resistance at welding heat affected zones. In cases where the sizes of grains are large in the Ca-Zn-Al intermetallic compound phase, the intermetallic compound phase easily forms an oxide layer of CaO with excellent adhesiveness at areas behind welded zones. That is, the effect to improve the corrosion resistance at areas behind welded zones is enhanced. Additionally, in cases where the sizes of grains are large in the Ca-Zn-Al intermetallic compound phase, the ratio of Zn linking to the Ca-Zn-Al intermetallic compound phase tends to increase, which prevents evaporation of the Zn phase and also improves the effect to reduce LME and blowhole formation.

If any treatment is applied to a plating layer originally having a low content of Zn phase to form coarse grains of a Ca-Zn-Al intermetallic compound phase, a tendency that the