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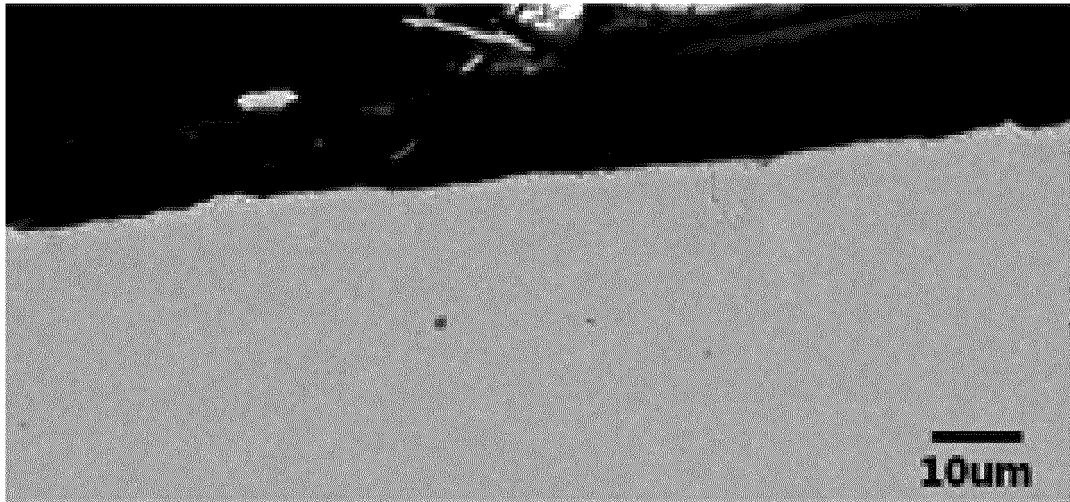
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(54) **HOT DIP GALVANIZED STEEL SHEET HAVING EXCELLENT RESISTANCE TO CRACKING DUE TO LIQUID METAL EMBRITTLEMENT**

(57) The objective of the present invention is to provide a molten zinc plated steel sheet with excellent crack resistance due to liquid metal bromide. One aspect of the present invention provides a molten zinc plated steel sheet with excellent crack resistance due to liquid metal bromide, the steel sheet comprising: a base steel sheet having a microstructure in which the fraction of austenite is greater than or equal to 90 area%; and a molten zinc plated layer formed on the base steel sheet, wherein the molten zinc plated layer comprises: a Fe-Zn alloy layer; and a Zn layer formed on the Fe-Zn alloy layer, and the

Fe-Zn alloy layer provides a molten zinc plated steel sheet having a thickness of $[(3.4 \times t)/6]$ μm or more with excellent crack resistance due to liquid metal bromide (where t is the thickness of the molten zinc plated steel sheet). The present invention can prevent a plated layer peeling phenomenon which easily occurs in common car welding and molding conditions, and can also provide a molten zinc plated steel sheet in which crack occurrence due to liquid metal bromide is suppressed.

【FIG. 3】



Description

[Technical Field]

5 **[0001]** The present disclosure relates to a hot-dip galvanized steel sheet having excellent resistance to cracking caused by liquid metal embrittlement.

[Background Art]

10 **[0002]** In general, body components of a vehicle are required to be lightweight while having stability. To this end, it is required to ensure high strength, ductility, and corrosion resistance in a steel sheet used for a component for a vehicle.

[0003] A representative technique therefor is disclosed in Patent Document 1. The technique relates to a Twinning-Induced Plasticity (TWIP) type ultra high strength steel sheet including 0.15 wt% to 0.30 wt% of carbon (C), 0.01 wt% to 0.03 wt% of silicon (Si), 15 wt% to 25 wt% of manganese (Mn), 1.2 wt% to 3.0 wt% of aluminum (Al), 0.020 wt% or less of phosphorus (P), 0.001 wt% to 0.002 wt% of sulfur (S), and iron (Fe) as a residual component thereof, and inevitable impurities, and a microstructure of steel is formed of a structure in an austenite phase. Ultra high tensile and high elongation are ensured, whereby the TWIP type ultra high strength steel sheet complies with vehicle body weight requirements.

20 **[0004]** On the other hand, a hot-dip steel sheet has excellent corrosion resistance, whereby such hot-dip steel sheets have been widely used in building materials, structures, household appliances, vehicle bodies, and the like. Types of hot-dip steel sheet which have been most recently widely used, can be divided into either a hot-dip galvanized steel sheet (hereinafter referred to as 'GI steel sheet') or an alloyed hot-dip galvanized steel sheet (hereinafter referred to as 'GA steel sheet').

25 **[0005]** A GI steel sheet is a steel sheet plated with molten zinc. The GI steel sheet can be easily plated, and has excellent corrosion resistance. Thus, the GI steel sheet has been widely used in vehicle bodies. A general GI steel sheet is a steel sheet in which a plating layer is formed as the GI steel sheet is submerged in a zinc plating bath to which 0.16 wt% to 0.25 wt% of Al has been added. In the GI steel sheet, the plating layer is composed mostly of zinc, but an alloying suppression layer capable of suppressing the alloying of iron and zinc is provided in a thickness of 1 μm or less at an interface between a base steel and a zinc plating layer. Thus, adhesion between a base steel and a plating layer is excellent. The alloying suppression layer is generally composed of $\text{Fe}_2\text{Al}_{5-x}\text{Zn}_x$.

30 **[0006]** On the other hand, to use the GI steel sheet as a component of a vehicle, spot-welding is generally performed. In this case, an alloying suppression layer formed in the GI steel sheet is melted by welding heat, thereby generating liquid zinc. More particularly, when spot-welding, a temperature of a welded portion is increased to about 1500°C or more within about 1 second, whereby a base steel and a plating layer are melted and welded. At this time, in a welding heat affected zone (HAZ) region, a temperature of a plating layer is increased to 600°C to 800°C. Thus, Fe is diffused in the plating layer, whereby a portion of the plating layer is alloyed to form an Fe-Zn alloy layer, and the remainder thereof is liquid zinc. The liquid zinc may penetrate into a grain boundary of a surface of a base steel and enters the grain boundary thereof. At this time, when tensile stress is applied to the HAZ, a crack having a size of about 10 μm to 100 μm may occur, thereby causing a brittle fracture phenomenon. This is referred to as liquid metal embrittlement (hereinafter referred to as 'LME'). In the case of a TWIP steel in which an austenite fraction is greater or the like, the TWIP steel has a higher resistance value than that of other types of steel, whereby the TWIP steel will be in a state of high temperature. In addition, as a grain boundary is expanded by a high thermal expansion coefficient, a liquid metal embrittlement problem may occur severely. In addition, in the case of TWIP steel, the TWIP steel has a higher thermal expansion coefficient than that of other types of steel such as a ferritic steel sheet and the like, whereby thermal stress may be caused. As a result, without external tensile stress, the thermal stress is applied to a welded portion, whereby the possibility of the occurrence of liquid metal embrittlement may be very high.

35 **[0007]** FIG. 1 is a view illustrating GI TWIP steel in which an LME crack is present in a welded portion. When an LME crack occurs as illustrated in FIG. 1, the LME crack causes fracturing of a steel sheet, whereby it may be difficult to use GI TWIP steel as a component for a vehicle and the like.

40 **[0008]** Because of these technical problems, with respect to a GI TWIP steel plate in which an austenite phase fraction is great, the development of a technology for improving resistance to cracking caused by liquid metal embrittlement after welding is required.

[Prior art document]

55 **[0009]** (Patent document 1) Korea Patent Laid-Open Publication No. 2007-0018416

[Disclosure]

[Technical Problem]

- 5 **[0010]** An aspect of the present disclosure is to provide a hot-dip galvanized steel sheet having excellent resistance to cracking caused by liquid metal embrittlement.

[Technical Solution]

- 10 **[0011]** According to an aspect of the present disclosure, a hot-dip galvanized steel sheet having excellent resistance to cracking caused by liquid metal embrittlement may include: a base steel sheet having a microstructure in which an austenite fraction is 90 area% or more; and a hot-dip galvanizing layer formed on the base steel sheet. The hot-dip galvanizing layer may include: an Fe-Zn alloy layer; and a Zn layer formed on the Fe-Zn alloy layer. The Fe-Zn alloy layer may have a thickness of $[(3.4 \times t)/6] \mu\text{m}$ or more, where t is a thickness of the hot-dip galvanizing layer.

15 [Advantageous Effects]

- [0012]** According to an exemplary embodiment in the present disclosure, provided is a hot-dip galvanized steel sheet in which plating layer delamination which may easily occur under vehicle welding and molding conditions according to the related art may be prevented, and the occurrence of cracking caused by liquid metal embrittlement may be suppressed.

[Description of Drawings]

[0013]

- 25 FIG. 1 is a view illustrating GI TWIP steel in which an LME crack occurs in a welded portion.
 FIG. 2A is a schematic view illustrating a cross section of existing GI TWIP steel, and FIG. 2B is a schematic view illustrating a cross section of a hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure.
 30 FIG. 3 is a view of a cross section of a welded portion of inventive example 1 according to an exemplary embodiment in the present disclosure.
 FIG. 4 is a view of a cross section of a welded portion of comparative example 1 outside of a range according to an exemplary embodiment in the present disclosure.

35 [Best Mode for Invention]

- [0014]** The inventors have conducted research into effectively suppressing the occurrence of cracking caused by liquid metal embrittlement (LME) when the above mentioned GI TWIP steel is manufactured. The present disclosure is proposed under the discovery that occurrence of cracking caused by LME may be prevented by suppressing the formation of a surface oxide used to suppress the diffusion of iron (Fe) and an Fe-Al or Fe-Al-Zn alloy layer, and by forming an Fe-Zn alloy layer having a sufficient thickness.

- [0015]** FIG. 2A is a schematic view illustrating a cross section of existing GI TWIP steel, and FIG. 2B is a schematic view illustrating a cross section of a hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure. Hereinafter, an exemplary embodiment in the present disclosure will be described with reference to FIG. 2.
 45 FIG. 2 schematically illustrates an exemplary embodiment in the present disclosure to illustrate the present disclosure, but does not limit the scope of the present disclosure.

- [0016]** As illustrated in FIG. 2A, in existing general GI TWIP steel, an alloying suppression layer (Fe-Al or Fe-Al-Zn alloy layer) 2 is formed on a base steel sheet 1, and a Zn layer 3 is formed on the alloying suppression layer 2. In addition, a surface oxide 4 such as MnO or the like exists between the base steel sheet 1 and the Zn layer 3. In a case of GI TWIP steel including a plating layer having such a structure, when spot-welding, liquid zinc is generated due to the alloying suppression layer 2, thereby causing LME cracking.

- [0017]** However, as illustrated in FIG. 2B, a hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure includes a base steel sheet 10, and a hot-dip galvanizing layer 20 formed on the base steel sheet. In this case, the hot-dip galvanizing layer 20 has a structure in which an Fe-Zn alloy layer 21 and a Zn layer 22 are sequentially formed. Thus, plating adhesion and excellent resistance to the occurrence of cracking caused by LME may be ensured.

- [0018]** As described above, the hot-dip galvanizing layer 20 according to an exemplary embodiment in the present disclosure formed on the base steel sheet 10 may preferably have a structure in which an Fe-Zn alloy layer 21 and a

Zn layer 22 are sequentially formed.

[0019] For a base steel sheet 100 applied to an exemplary embodiment in the present disclosure, TWIP steel in which a cracking problem caused by LME severely occurs as described above, is a target. Accordingly, a hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure may preferably have a microstructure in which an austenite fraction is 90 area% or more. In addition, in order to ensure the above-mentioned microstructure and to ensure excellent mechanical properties and the like, a base steel sheet used in a hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure may include, by wt%, carbon (C): 0.10% to 0.30%, manganese (Mn): 10% to 30%, silicon (Si): 0.01% to 0.03%, titanium (Ti): 0.05% to 0.2%, manganese (Mn): 10% to 30%, aluminum (Al): 0.5% to 3.0%, nickel (Ni): 0.001% to 10%, chromium (Cr): 0.001% to 10%, nitrogen (N): 0.001% to 0.05%, phosphorus (P): 0.020% or less, sulfur (S): 0.001% to 0.005%, and iron (Fe) as a residual component thereof, and inevitable impurities.

[0020] According to an exemplary embodiment in the present disclosure, the Fe-Zn alloy layer 21 is formed to have a sufficient thickness. The Fe-Zn alloy layer 21 allows the formation of liquid zinc to be decreased, thereby suppressing occurrence of cracking caused by LME. To suppress occurrence of cracking caused by LME, when welding, it is advantageous to allow Fe to be quickly diffused and then Fe to react with Zn, thereby forming an Fe-Zn alloy layer. Thus, as Zn preferentially reacts with Fe, the transformation of Zn into liquid zinc due to a heat effect caused by welding may be suppressed. Thus, according to an exemplary embodiment in the present disclosure, the Fe-Zn alloy layer 21 is formed to a sufficient thickness in advance, thereby improving the above-described effect. To this end, it may be preferable that a thickness of the Fe-Zn alloy layer be $[(3.4 \times t)/6]$ μm or more. When a thickness of the Fe-Zn alloy layer is less than $[(3.4 \times t)/6]$ μm , an effect of suppressing occurrence of cracking caused by LME may not be sufficiently obtained. On the other hand, the above described t refers to a thickness of the hot-dip galvanizing layer. According to an exemplary embodiment in the present disclosure, as a thickness of the Fe-Zn alloy layer is increased, a preferable effect may be obtained. Thus, an upper limit of the Fe-Zn alloy layer thickness is not particularly limited.

[0021] Furthermore, it may be preferable that the Fe-Zn alloy layer 21 includes Fe of 3 wt% to 15 wt%. When Fe contents inside the Fe-Zn alloy layer are less than 3 wt%, in an amount the same as that of an existing GI steel sheet, there may be a disadvantage that cracking caused by LME occurs. When Fe contents inside the Fe-Zn alloy layer are more than 15 wt%, a problem of decreasing workability may occur.

[0022] Zn may remain as a Zn layer on the Fe-Zn alloy layer 21 as Zn does not react to Fe.

[0023] On the other hand, according to an exemplary embodiment in the present disclosure, it may be preferable to suppress the formation of an Fe-Al or Fe-Al-Zn alloy layer 23 formed in a lower part of the hot-dip galvanizing layer 20, in other words, between a base steel sheet 10 and an Fe-Zn alloy layer 21 as possible. The Fe-Al or Fe-Al-Zn alloy layer 23 may cause cracking caused by LME by forming liquid zinc when welding. Thus, according to an exemplary embodiment in the present disclosure, a thickness of the Fe-Al or Fe-Al-Zn alloy layer 23 is formed to be as thin as possible. On the other hand, according to an exemplary embodiment in the present disclosure, component contents of the Fe-Al and Fe-Al-Zn alloy layer are not particularly limited. For example, the Fe-Al alloy layer may be Fe_2Al_5 , and the Fe-Al-Zn alloy layer may be $\text{Fe}_2\text{Al}_5\text{Zn}_x$.

[0024] In addition, it may be preferable that the alloy layer 23 includes 0.3 wt% or less of Al. When Al contents contained in the alloy layer 23 exceed 0.3 wt%, diffusion of Fe is suppressed. Thus, it may be difficult to ensure an Fe-Zn alloy layer having a sufficient thickness.

[0025] On the other hand, it may be preferable that an Fe-Ni alloy layer 30 is further included directly below a surface of the base steel sheet. More particularly, the Fe-Ni alloy layer 30 may ensure excellent plating adhesion as MnO or the like exists as an internal oxide 40 by suppressing a surface oxide such as MnO or the like from being formed, as an oxidizing element such as Mn or the like is enriched on a surface of the Fe-Ni alloy layer 30, in the manner of TWIP steel. To ensure the above effect, the Fe-Ni alloy layer may be formed by a Ni coating layer having an adhesion amount of 300 mg/m^2 to 1000 mg/m^2 , and a thickness of the Fe-Ni alloy layer may be different according to manufacturing conditions. For example, a thickness of the Fe-Ni alloy layer may have a range of 0.05 μm to 5 μm . When the Fe-Ni alloy layer is formed to have a thickness less than 0.05 μm , zinc wettability is decreased, thereby being non-plated or decreasing plating adhesion. On the other hand, in the case that a thickness of the Fe-Ni alloy layer exceeds 5 μm , a problem that an amount of Fe diffused into a plating layer from a base steel sheet is reduced may occur, and manufacturing costs may be sharply increased.

[0026] In addition, one or more type selected from a group consisting of an Fe-X alloy layer, an Fe-Al-X alloy layer, an Fe-Al-Zn-X alloy layer, and an Fe-Zn-X alloy layer may be additionally included between the base steel sheet and the hot-dip galvanizing layer. As the alloy layer is formed, plating adhesion and excellent resistance to occurrence of cracking caused by LME may be ensured. The above-described X, for example, is a material which may have cations inside an electroplating solution, and the X may be one of Ni and Cr.

[0027] The hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure provided as described above may ensure excellent resistance to cracking caused by LME, and may ensure an excellent level of plating adhesion, a physical property typically required in a hot-dip galvanized steel sheet.

[0028] On the other hand, the hot-dip galvanized steel sheet according to an exemplary embodiment in the present disclosure may be manufactured by various methods. Preferably, after a Ni coating layer is formed on a base steel sheet, the base steel sheet is heated to a temperature of 700°C to 900°C in a reducing atmosphere furnace charged with a H₂-N₂ mixed gas, and the heated base steel sheet is cooled. Then, the base steel sheet is submerged in a molten zinc plating bath at 440°C to 460°C including 0.13 wt% or less of Al. Thus, the hot-dip galvanized steel sheet may be manufactured by using the above-mentioned method. As a person of ordinary skill in the art is able to easily control other conditions without separate and repetitive experimentation, the hot-dip galvanized steel sheet proposed according to an exemplary embodiment in the present disclosure may be manufactured.

[0029] First, a base steel sheet having a microstructure in which an austenite fraction is 90 area% or more, is prepared. The base steel sheet as TWIP steel, has a high austenite fraction. To this end, the base steel sheet includes a large amount of Mn, Al, Ni, and the like such as an oxidizing element. Thus, a surface of the base steel sheet is required to be cleaned beforehand. For example, to remove foreign substances or an oxide film or the like from a surface thereof, it may be preferable to perform a pickling or cleaning process. When the pickling or cleaning process is not performed, a coating layer or a plating layer is not uniform, and a plating appearance or adhesion may be decreased.

[0030] A Ni coating layer is formed on the prepared base steel sheet as described above. Formation of the Ni coating layer may be performed by electro-plating. Thus, a coating layer having a uniform thickness may be formed. On the other hand, the Ni coating layer preferably has an adhesion of 300 mg/m² to 1000 mg/m². When an adhesion of the Ni coating layer is less than 300 mg/m², an Fe-Ni alloy layer having a sufficient thickness is not formed. Thus, a surface enrichment amount of Mn is not sufficiently suppressed, and zinc wettability is also decreased, thereby causing a non-plating phenomenon or decreasing plating adhesion. When an adhesion amount of the Ni coating layer exceeds 1000 mg/m², an amount of Fe diffused into a plating layer from a base steel sheet is decreased by forming an Fe-Ni alloy layer in which Ni contents are high. Thus, an Fe-Zn alloy layer having a sufficient thickness may not be obtained, and manufacturing costs may be sharply increased.

[0031] Hereafter, the base steel sheet having the Ni coating layer is heated to a temperature of 700°C to 900°C in a reducing atmosphere furnace charged with a H₂-N₂ mixed gas. Through the heating process, Ni in the Ni coating layer may penetrate into an interior of the base steel sheet, thereby forming an Fe-Ni alloy layer. When the heating temperature is lower than 700°C, a steel sheet structure is not transformed into a structure formed in an austenite phase after cold-rolling the steel sheet structure. When the heating temperature exceeds 900°C, chances that deformation and fractures will occur in a steel sheet are increased.

[0032] On the other hand, as a fraction of the H₂-N₂ mixed gas used for forming a reducing atmosphere which is commonly used in the art, is used, such a fraction of the H₂-N₂ mixed gas is not particularly mentioned according to an exemplary embodiment in the present disclosure.

[0033] After heating, it may be preferable that the base steel sheet is maintained in the heating temperature range for 20 or more seconds. When the retention time is less than 20 seconds, an Fe-Ni alloy layer having a sufficient thickness is not formed. Thus, a surface enrichment amount of Mn is not sufficiently suppressed.

[0034] Next, the heated base steel sheet is cooled to a temperature between 400°C to 500°C at a cooling rate of 5°C/s or more. When the cooling rate is less than 5°C/s, it may be difficult to obtain austenite of 90 area% or more.

[0035] After cooling, a plating bath insertion temperature of the cooled base steel sheet is controlled to have a range of (molten zinc plating bath-40°C) to (molten zinc plating bath+10°C). When the plating bath insertion temperature is lower than (molten zinc plating bath-40°C), Fe contained in a base steel sheet is less eluted, thereby suppressing formation of a structure in an Fe-Zn alloy phase. When the plating bath insertion temperature exceeds (molten zinc plating bath+10°C), an Fe-Al or Fe-Al-Zn alloy layer is thickly formed, thereby interfering in diffusion of Fe. On the other hand, controlling a plating bath insertion temperature of the base steel sheet may be performed by cooling the base steel sheet when the cooling stop temperature is higher than the plating bath insertion temperature, maintaining the base steel sheet at temperature when the cooling stop temperature is the same as the plating bath insertion temperature, and heating the base steel sheet when the cooling stop temperature is lower than the plating bath insertion temperature.

[0036] The base steel sheet controlled in a range of the plating bath insertion temperature is submerged into a molten zinc plating bath at 440°C to 460°C including 0.13 wt% or less of Al, whereby a plating solution is applied to a surface of the base steel sheet. When contents of Al of the molten zinc plating bath exceed 0.13 wt%, diffusion of Fe is suppressed, whereby it may be difficult to obtain an Fe-Zn alloy layer having a sufficient thickness. When a temperature of the molten zinc plating bath is lower than 440°C, it may be difficult to ensure fluidity of a plating solution, whereby plating may not be performed smoothly. When a temperature of the molten zinc plating bath exceeds 460°C, a problem that a plating solution is volatilized or the like, may occur.

[0037] Hereafter, the base steel sheet to which the plating solution is applied, is slowly cooled at a slow cooling rate of 4°C/s to 20°C/s, thereby forming a hot-dip galvanizing layer. When the slow cooling rate is lower than 4°C/s, unsolidified zinc may be smeared on equipment such as a roll, thereby causing secondary product defects. When the slow cooling rate exceeds 20°C/s, there may be a disadvantage that the Fe-Zn alloy layer does not grow enough to have a sufficient thickness.

[0038] Through a process as described above, an Fe-Ni alloy layer is formed directly below a surface of the base steel sheet, and Fe contained inside the base steel sheet is diffused to a plating layer simultaneously. Thus, a hot-dip galvanizing layer having a structure required according to an exemplary embodiment in the present disclosure may be formed on the base steel sheet.

[0039] Hereinafter, the present disclosure will be described more in detail through an exemplary embodiment. However, the below exemplary embodiment is an example for describing the present disclosure more in detail, but does not limit the scope of the present disclosure.

(Example)

[0040] After a cold-rolled TWIP base steel sheet was cleaned by alkalic degreasing and pickling the cold-rolled TWIP base steel sheet, a Ni coating layer was formed on the base steel sheet through electro-plating and provided as an adhesion amount in table 1 (comparative examples 2 to 4 were not carried out) . Next, after the base steel sheet was heated under the conditions of table 1 in a reducing atmosphere furnace charged with a 5% H₂-N₂ mixed gas, the base steel sheet was cooled to 400°C. In addition, after a plating bath insertion temperature was controlled, the base steel sheet was submerged in a molten zinc plating bath at 460°C, and then a plating solution was applied to the base steel sheet. After a plating adhesion amount was controlled by air-knifing the base steel sheet to which the plating solution was applied, the base steel sheet was slowly cooled under the conditions of table 1, thereby forming an Fe-Ni alloy layer directly below a surface of the base steel sheet. In addition, a hot-dip galvanized steel sheet in which a hot-dip galvanizing layer was formed of an Fe-Al or Fe-Al-Zn alloy layer, an Fe-Zn alloy layer, and a Zn layer, was manufactured. After a thickness of the Fe-Zn alloy layer of the hot-dip galvanized steel sheet was measured, and plating adhesion was evaluated, results thereof were shown in table 1. In addition, after the hot-dip galvanized steel sheet was spot-welded at a welding current of 5.8 kA, a size of individual cracks caused by LME was measured, and results thereof were shown in table 1. On the other hand, the plating adhesion evaluation was conducted by checking whether a plating material was smeared on tape after bending a hot-dip galvanized steel sheet through 180°. When the plating material was smeared on the tape, it was shown as separation. When plating material was not smeared on the tape, it was shown as non-separation.

[Table 1]

Classification	Ni adhesion amount (mg/m ²)	Heating temperature (°C)	Plating bath insertion temperature (°C)	Plating bath Al contents (wt%)	Plating adhesion amount (g/m ²)	Slow cooling rate (°C/s)	Fe-Zn alloy layer thickness (μm)	Plating adhesion	LME crack length (μm)
comparative example1	300	760	480	0.2	60	10	0	non-sepa ration	24.5
comparative example2	-	760	420	0.12	60	10	1.6	separati on	37.0
comparative example3	-	760	460	0.12	60	10	1.8	separati on	25.5
comparative example4	-	760	500	0.12	60	10	0.8	separati on	40.0
comparative example5	300	760	420	0.12	60	10	2.3	non-sepa ration	6.3
comparative example6	300	760	460	0.12	60	10	2.3	non-sepa ration	7.3
comparative example7	300	760	500	0.12	60	10	2.0	non-sepa ration	23.0
comparative example8	500	760	420	0.12	60	10	2.9	non-sepa ration	6.3
comparative example9	500	760	460	0.12	60	10	3.7	non-sepa ration	2.8
inventive example1	780	760	450	0.12	60	10	4.8	non-sepa ration	0
inventive example2	500	760	460	0.12	45	10	3.8	non-sepa ration	0

[0041] As shown in above table 1, in a case of inventive examples 1 and 2 having a hot-dip galvanizing layer satisfying a thickness of an Fe-Zn alloy layer proposed by an exemplary embodiment in the present disclosure, it may be seen that plating adhesion was excellent and cracking caused by LME did not occur at all.

[0042] On the other hand, in a case of comparative example 1, contents of an Al plating bath were excessive, thereby not forming an Fe-Zn alloy layer. Thus, it may be seen that cracking caused by LME occurred in a level of 24.5 μm .

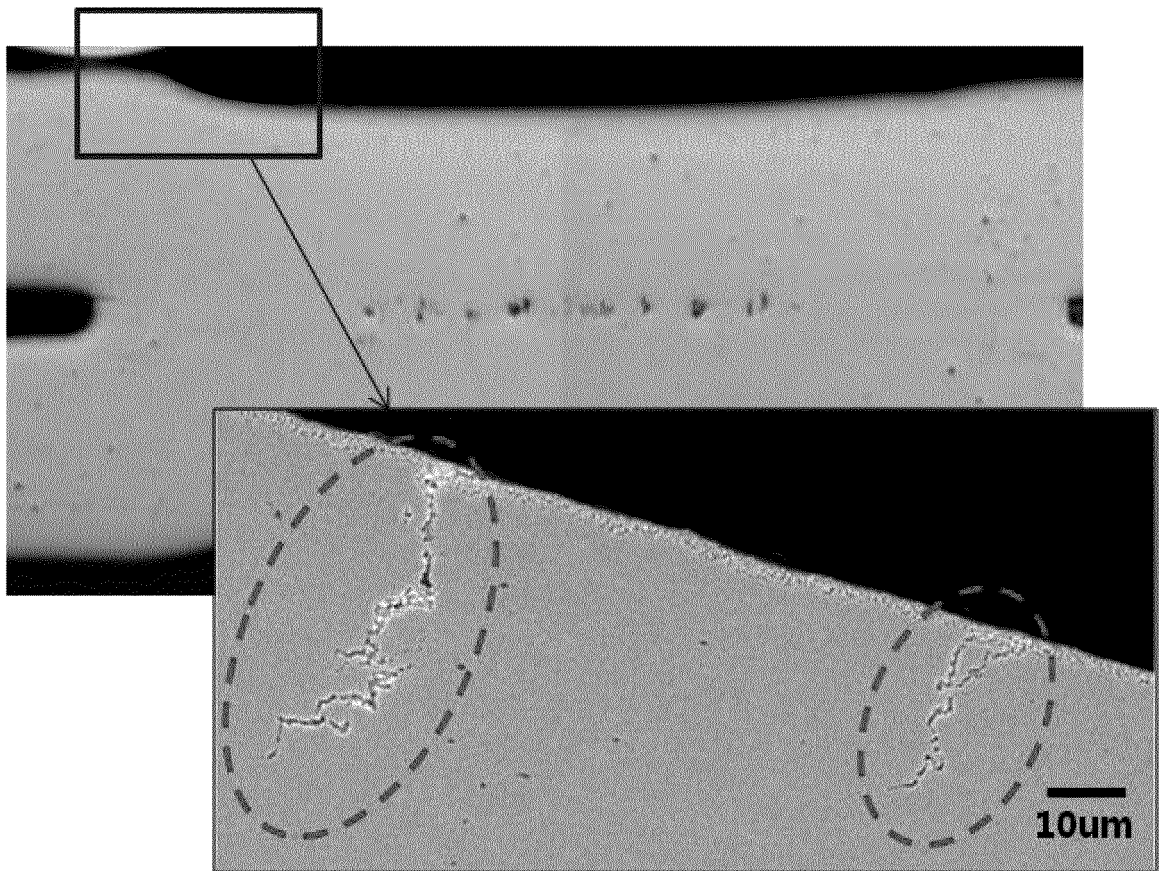
[0043] In a case of comparative examples 2 to 4, as a Ni coating layer was not formed, it may be seen that all plating layers were separated. As an Fe-Zn alloy layer thickness proposed by an exemplary embodiment in the present disclosure was not satisfied, it may be seen that cracking caused by LME severely occurred.

[0044] In a case of comparative examples 4 to 9, as an Fe-Zn alloy layer having a sufficient thickness proposed by an exemplary embodiment in the present disclosure was not formed, it may be seen that cracking caused by LME occurred.

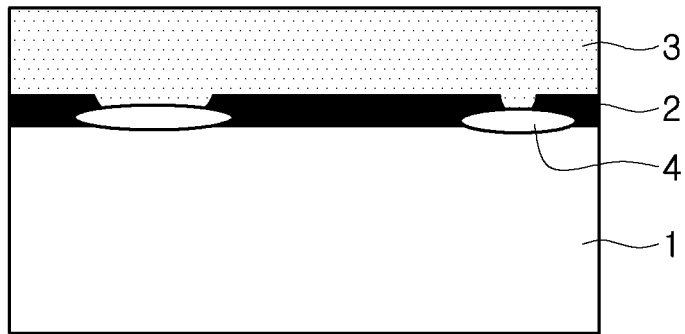
Claims

1. A hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement, comprising:
 - a base steel sheet having a microstructure in which an austenite fraction is 90 area% or more; and
 - a hot-dip galvanizing layer formed on the base steel sheet,
 - wherein the hot-dip galvanizing layer includes an Fe-Zn alloy layer, and a Zn layer formed on the Fe-Zn alloy layer, and the Fe-Zn alloy layer has a thickness of $[(3.4 \times t) / 6] \mu\text{m}$ or more, where t is a thickness of the hot-dip galvanizing layer.
2. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, wherein the Fe-Zn alloy layer includes 3 wt% to 15 wt% of iron (Fe).
3. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, wherein the base steel sheet comprises, by wt%, carbon (C) : 0.10% to 0.30%, manganese (Mn) : 10% to 30%, silicon (Si) : 0.01% to 0.03%, titanium (Ti): 0.05% to 0.2%, manganese (Mn): 10% to 30%, aluminum (Al): 0.5% to 3.0%, nickel (Ni): 0.001% to 10%, chromium (Cr): 0.001% to 10%, nitrogen (N): 0.001% to 0.05%, phosphorus (P): 0.020% or less, sulfur (S): 0.001% to 0.005%, and iron (Fe) as a residual component thereof, and inevitable impurities.
4. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, wherein the hot-dip galvanizing layer further includes an Fe-Al or Fe-Al-Zn alloy layer below the Fe-Zn alloy layer.
5. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 4, wherein the alloying suppression layer includes 0.6 wt% or less of aluminum (Al).
6. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, further comprising an Fe-Ni alloy layer disposed directly below a surface of the base steel sheet.
7. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, wherein the Fe-Ni alloy layer is provided by coating Ni having an adhesion amount of 300 mg/m² to 1000 mg/m².
8. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, wherein the Fe-Ni alloy layer has a thickness of 0.05 μm to 5 μm .
9. The hot-dip galvanized steel sheet having excellent resistance to cracking due to liquid metal embrittlement of claim 1, further comprising one or more selected from a group consisting of an Fe-X alloy layer, an Fe-Al-X alloy layer, an Fe-Al-Zn-X alloy layer, and an Fe-Zn-X alloy layer, disposed between the base steel sheet and the hot-dip galvanizing layer, where X is one of nickel (Ni) and chromium (Cr).

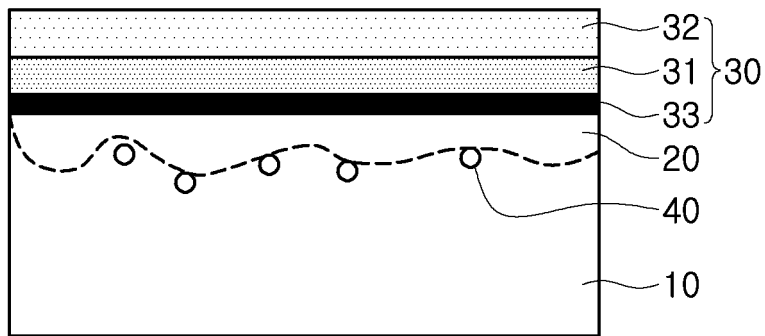
【FIG. 1】



【FIG. 2】



(a)

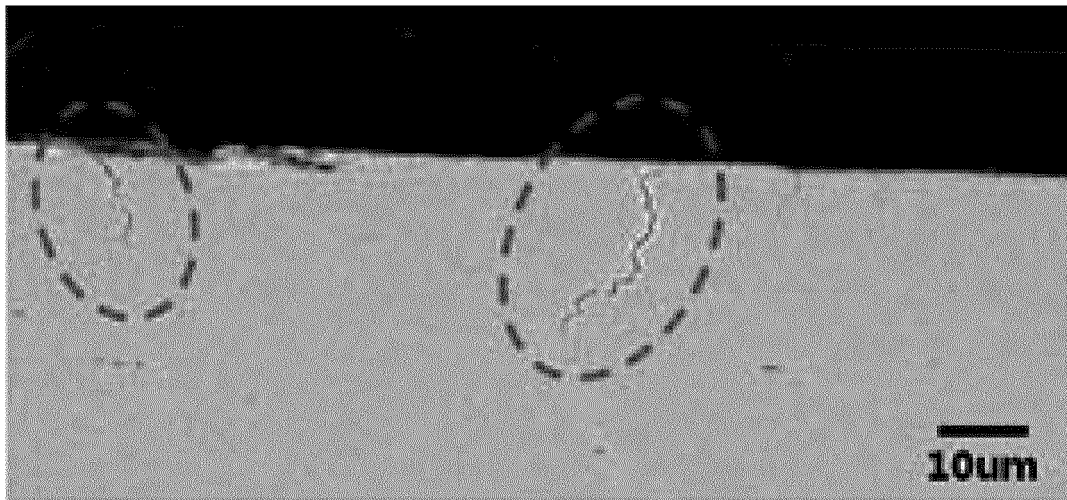


(b)

【FIG. 3】



【FIG. 4】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2014/012824

A. CLASSIFICATION OF SUBJECT MATTER

C23C 2/06(2006.01)i, C23C 28/00(2006.01)i, C22C 38/00(2006.01)i

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)

C23C 2/06; C21D 9/46; C23C 2/02; C23C 2/28; C22C 38/00; C25D 5/26; C22C 38/60; C23C 28/00

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

Korean Utility models and applications for Utility models: IPC as above

Japanese Utility models and applications for Utility models: IPC as above

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

eKOMPASS (KIPO internal) & Keywords: austenite, TWIP steel, galvanized steel plating layer, Fe-Zn alloy layer, Zn layer, liquid metal embrittlement, crack resistance, allowing suppressing layer, Fe-Ni alloy layer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 4329639 B2 (SUMITOMO METAL IND., LTD.) 09 September 2009 See abstract; paragraphs [0022]-[0025]; claims 1 and 2.	1-9
A	KR 10-2013-0026133 A (POSCO) 13 March 2013 See abstract; paragraphs [0021], [0029]-[0034]; claims 1-3, 5, 10 and 11.	1-9
A	JP 2004-124187 A (SUMITOMO METAL IND., LTD.) 22 April 2004 See abstract; paragraphs [0033]-[0038], [0043]-[0046]; claims 1 and 4-6.	1-9
A	JP 2012-197505 A (JFE STEEL CORP.) 18 October 2012 See abstract; paragraphs [0016]-[0022]; claims 1 and 2.	1-9
A	KR 10-2013-0002228 A (POSCO) 07 January 2013 See abstract; paragraphs [0026], [0027], [0040]-[0042]; claims 1-9; figures 1 and 4.	1-9

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

* Special categories of cited documents:

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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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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

30 MARCH 2015 (30.03.2015)

Date of mailing of the international search report

31 MARCH 2015 (31.03.2015)

Name and mailing address of the ISA/KR


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 Republic of Korea

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Authorized officer

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2014/012824

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KR 10-2013-0002228 A	07/01/2013	KR 10-1359183 B1	06/02/2014

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 20070018416 [0009]