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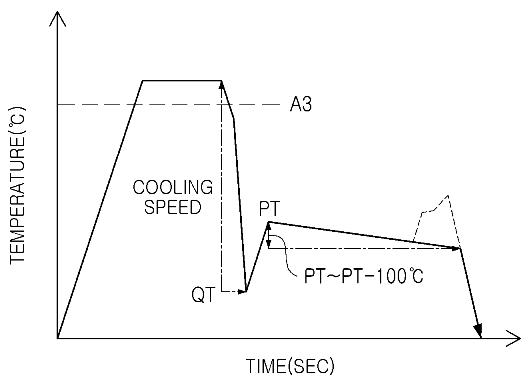
(54) HIGH STRENGTH COLD ROLLED STEEL PLATE HAVING EXCELLENT YIELD STRENGTH, DUCTILITY, AND HOLE EXPANDABILITY, HOT DIP GALVANIZED STEEL PLATE, AND METHOD FOR PRODUCING SAME

(57) Provided are a high strength cold rolled steel sheet having excellent yield strength, ductility, and hole expandability, a hot dip galvanized steel sheet, and a method for producing same. The cold rolled steel sheet of the present invention comprises 0.06-0.2 wt% of carbon (C), 1.5-3.0 wt% of manganese (Mn), 0.3-2.5 wt% of silicon (Si), 0.01-0.2 wt% of aluminum (Al), 0.01-3.0 wt% of nickel (Ni), 0.2 wt% or less of molybdenum (Mo), 0.01-0.05 wt% of titanium (Ti), 0.02-0.05 wt% of antimony (Sb), 0.0005-0.003 wt% of boron (B), 0.01 wt% or less (but not 0%) of nitrogen (N), with the remainder comprising Fe and unavoidable impurities, and the microstructure thereof comprises, in terms of area fraction, 50% or more of bainite, 10% or more of tempered martensite (TM), 10% or less of fresh martensite (FM), 20% or less of residual austenite, and 5% or less of ferrite.

【Fig. 1】



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Description

[Technical Field]

[0001] The present disclosure relates to a high strength steel sheet used in a vehicle body, and more particularly, to a high strength cold-rolled steel sheet having high strength, excellent yield strength and formability at the same time such that the high strength steel sheet may have excellent press formability, an hot-dip galvanized steel sheet, and a method of manufacturing the same.

[Background Art]

[0002] To reduce a weight of a steel sheet applied as a structural member of a means of transportation such as construction materials, vehicles, and trains by reducing a thickness of a steel sheet, there have been many attempts to improve strength of conventional steel materials. However, it has been found that, when strength increases as above, there may be disadvantages of low yield strength and degradation of ductility and hole expandability.

[0003] Accordingly, a large volume of research has been conducted to improve the relationship between strength and ductility, and as a result, a transformed structural steel which uses martensite, a low temperature structure, bainite, and also a residual austenite phase has been developed and applied.

[0004] As transformed structure steel, there may be DP (dual phase) steel, TRIP (transformation induced plasticity) steel, CP (complex phase) steel, and the like, and the steels may have different mechanical characteristics, that is, different levels of tensile strength and an elongation rate, depending on types and fractions of a base phase and a secondary phase. Particularly, as for TRIP steel including residual austenite, a balance (TS×El) between tensile strength and an elongation rate may appear to be the highest value.

[0005] CP steel among the transformed structure steels as above may have a low elongation rate, as compared to the other steels, such that CP steel may only be used in a simple process such as a roll forming process, and the like, and DP steel and TRIP steel having high ductility may be applied to a cold press forming process, and the like.

[0006] Accordingly, recently, a technique of providing deep drawability and presenting flange portion cracks by increasing ductility further than those of DP steel and TRIP steel, transformed structure steels, and by increasing hole expandability has been suggested. As an example, reference 2 discloses a method (quenching and partitioning process, Q&P) of forming residual austenite and martensite as a main structure. However, according to a report (non-patent reference 1) using the method, when carbon decreases to a 0.2% level, there may be a disadvantage in which yield strength may be low, about 400MPa. Further, it has been found that an elongation rate obtained from a final product may be similar to a level of an elongation rate of conventional TRIP steel. A gist of the Q&P method may be to quench steel to a temperature between a martensite transformation starting temperature (Ms) and a finish temperature (Mf) and to reheat the steel such that carbon diffusion may occur on an interfacial surface between martensite and austenite and may stabilize austenite, thereby securing ductility. However, there may be a significant amount of austenite which may not be stabilized depending on the quenching and partitioning temperature such that fresh martensite (FM) may be formed in a final cooling process. Fresh martensite has a high content of carbon such that hole expandability may be deteriorated (reference 3).

[0007] As a different method, there may be a method of performing a heat treatment on a martensite structure again and performing a heat treatment in a two-phase region to secure ductility and hole expandability, but the method is not economical in that a heat treatment is performed twice (reference 4).

[0008] Lastly, a method of performing a heat treatment on steel using a general annealing method, rapidly cooling the steel to a bainite formation regoin, and isothermal maintaining the steel for a long time, thereby obtaining a bainite structure has been developed. However, the isothermal maintaining time may be too long, and incompletely transformed bainite may form martensite in a final cooling process, and thus, hole expandability may be poor.

[Prior Art]

{Patent Reference}

[0009]

(Reference 1) Korean Laid-Open Patent Publication No. 1994-0002370
(Reference 2) U.S. Laid-Open Publication No. 2006-0011274
(Reference 3) Japanese Patent Publication JP2002-177278
(Reference 4) Japanese Patent Publication JP2001-300503
(Reference 5) Japanese Patent Publication JP2014-018431

{Non-Patent Reference}

[0010] (Non-Patent Reference 1) ISIJ International, Vol.51, 2011, p.137-144

[Disclosure]

[Technical Problem]

[0011] Thus, the present disclosure has been devised to resolve the limitations of the conventional techniques described above, and the purpose of the present disclosure is to implement low alloy raw material costs as compared to that of conventional TWIP steel and to provide a cold-rolled steel sheet including a bainite main phase which may have excellent ductility and hole expandability as compared to a case in which a conventional TPF (trip aided bainitic ferrite) Q&P (quenching and partitioning) heat treatment process is applied, a hot-dip galvanized steel sheet manufactured using the same, an alloyed hot-dip galvanized steel sheet, and a method of manufacturing the aforementioned steel sheets.

[0012] The technical problems which the present disclosure tries to resolve are not limited to the technical problems described above, and other unmentioned technical problems will be explicitly understandable to a person having ordinary skill in the art.

[Technical Solution]

[0013] The present disclosure for achieving the aforementioned purposes relates to high strength cold-rolled steel sheet having excellent yield strength, ductility, and hole expandability comprising, by wt%, 0.06 to 0.2% of carbon (C), 1.5 to 3.0% of manganese (Mn), 0.3 to 2.5% of silicon (Si), 0.01 to 0.2% of aluminum (Al), 0.01 to 3.0% of nickel (Ni), 0.2% or less of molybdenum (Mo), 0.01 to 0.05% of titanium (Ti), 0.02 to 0.05% of antimony (Sb), 0.0005 to 0.003% of boron (B), 0.01% or less of nitrogen (N), excluding 0, and a balance of Fe and inevitable impurities, and a microstructure thereof comprises, by area fraction, bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less.

[0014] It may be preferable for a TM/FM ratio to exceed 2.

[0015] The present disclosure also relates to a hot-dip galvanized steel sheet manufactured by hot-dip zinc plating a surface of the cold-rolled steel sheet, and an alloyed hot-dip galvanized steel sheet manufactured by alloy hot-dip zinc plating a surface of the cold-rolled steel sheet.

[0016] Also, the present disclosure relates to a method of manufacturing a high strength cold-rolled steel sheet having excellent yield strength, ductility, and hole expandability, the method comprising reheating a steel slab comprising by wt%, 0.06 to 0.2% of carbon (C), 1.5 to 3.0% of manganese (Mn), 0.3 to 2.5% of silicon (Si), 0.01 to 0.2% of aluminum (Al), 0.01 to 3.0% of nickel (Ni), 0.2% or less of molybdenum (Mo), 0.01 to 0.05% of titanium (Ti), 0.02 to 0.05% of antimony (Sb), 0.0005 to 0.003% of boron (B), 0.01% or less, excluding 0, of nitrogen (N), and a balance of Fe and inevitable impurities, hot-rolling the steel slab, and performing a coiling process; and cold-rolling and continuously Q&P annealing the coiled hot-rolled steel sheet, and the continuous Q&P annealing comprises uniformly heating the manufactured cold-rolled steel sheet to an Ac3 temperature or higher for 30 seconds or longer, and cooling the cold-rolled steel sheet to a quenching temperature(QT)±10°C defined by Relational Expression 1 below at a cooling rate of 5 to 20°C/sec, and reheating the cooled steel sheet to a bainite temperature (PT)±10°C defined by Relational Expression 2 below, maintaining the steel sheet within a temperature range of QT≥ or ≥ QT-100°C for 100 seconds, and cooling the steel sheet.

[Relational Expression 1]

$$QT = 493.497 + 36.2874\times Al - 394.0\times C - 45.0\times Mn - 11.4332\times Mo - 20.8772\times Ni - 13.0438\times Si - 12.8\times Cr$$

[Relational Expression 2]

$$PT = 599.088 + 11.5214\times Al - 225.2\times C - 35.0\times Mn - 19.9474\times Ni - 24.9385\times Si - 56.718\times Mo - 22.1\times Cr$$

[0017] The steel sheet after the continuous Q&P annealing may have a microstructure including, by area fraction, bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less.

[0018] It may be preferable for a TM/FM ratio to exceed 2.

[0019] The present disclosure also relates to a method of manufacturing a hot-dip galvanized steel sheet comprising hot-dip zinc plating a surface of the continuously Q&P annealed cold-rolled steel sheet, and a method of manufacturing an alloyed hot-dip galvanized steel sheet comprising alloy hot-dip zinc plating a surface of the continuously Q&P annealed cold-rolled steel sheet.

[Advantageous Effects]

[0020] According to the present disclosure including the above-described features, an accurate amount of TM and bainite may be secured as compared to high ductility transformed structure steel such as conventional DP steel or TRIP steel and Q&P steel formed through a conventional Q&P (quenching & partitioning) heat treatment. Thus, a high strength cold-rolled steel sheet having excellent tensile strength of 980MPa or higher and thus having excellent yield strength, ductility, and hole expandability, a hot-dip galvanized steel sheet, and an alloyed hot-dip galvanized steel sheet may be effectively provided.

[0021] Thus, the cold-rolled steel sheet, and the like, may have an advantage of high usability in the industrial fields such as building materials, vehicle steel sheets, and others.

[Description of Drawings]

[0022]

FIG. 1 is a graph of an example of an annealing process according to the present disclosure (in FIG. 1, a dotted line among heat treatment lines indicates a thermal history during a hot-dip alloy plating process);
FIG. 2 is graphs illustrating the low temperature transformation movement of a TBF method and of a method of the present disclosure;
FIG. 3 is an image of a microstructure of inventive example steel (F) manufactured by the present disclosure;
FIG. 4 is results of observation of carbides in tempered martensite of a cold-rolled steel sheet manufactured by the present disclosure; and
FIG. 5 is an image of a microstructure of comparative example (E) steel.

[Best Mode for Invention]

[0023] The inventors have conducted research into a method for improving low ductility of high strength steel manufactured through a conventional Q&P (quenching & partitioning) method, and have found a heat treatment condition in which bainite transformation may be facilitated in a certain temperature range, which is more accurate than that of the conventional technique, and FM may significantly reduce during a Q&P heat treatment. It has been found that, by controlling QT and PT based on an amount of martensite formation and a bainite transformation facilitated region by quenching, refinement of a structure after a final Q&P heat treatment and properties of a final product may improve, and the present disclosure has been suggested.

[0024] Hereinafter, the present disclosure will be described in detail.

[0025] An alloy element composition and the reasons for limiting contents thereof of a cold-rolled steel sheet provided in the present disclosure will be described in detail. A content of each element may indicate weight% unless otherwise indicated.

C: 0.06 to 0.2%

[0026] Carbon (C) is an element which may be effective for strengthening steel. In the present disclosure, C is an important element which may be added to stabilize residual austenite and to secure strength. To obtain the above-described effect, it may be preferable to add 0.06% or higher of C. When a content of C is lower than 0.06%, a temperature of an austenite phase may excessively increase such that a high temperature annealing process may be inevitable, and it may be difficult to secure strength and ductility. When a content of C exceeds 0.2%, Ms may decrease, such that a quenching temperature may decrease, and it may be difficult to perform an accurate heat treatment. Weldability may also greatly degrade, which may be another problem. Thus, in the present disclosure, it may be preferable to limit a content of C to 0.06 to 0.2%.

Mn: 1.5 to 3.0%

[0027] Manganese (Mn) is an element which may be effective for forming and stabilizing residual austenite while controlling the transformation of ferrite. When a content of Mn is lower than 1.5%, a large amount of ferrite transformation may occur such that there may be the problem in which it may be difficult to secure target strength. When a content of Mn exceeds 3.0%, phase transformation in a secondary annealing heat treatment of the present disclosure may be excessively delayed such that a large amount of martensite may be formed, and it may be difficult to secure intended ductility, which may be a problem. Thus, it may be preferable to limit a content of Mn to 1.5 to 3.0%.

Si: 0.3 to 2.5%

[0028] Silicon (Si) is an element which may prevent the precipitation of carbides in ferrite, may facilitate the diffusion of carbon in ferrite to austenite, and may consequently contribute to the formation of bainite and stabilization of residual austenite. To obtain the above-described effect, it may be preferable to add 0.3% or higher of Si. However, when a content of Si exceeds 2.5%, hot and cold rolling properties may be greatly deteriorated, and oxides may be formed on a surface of steel such that coatability may be deteriorated, which may be a problem. Thus, in the present disclosure, it may be preferable to limit a content of Si to 0.3 to 2.5%.

Al: 0.01 to 0.2%

[0029] Aluminum (Al) is an element which may cause deoxidation by being combined with oxygen in steel. To this end, it may be preferable to maintain a content of Al to be 0.01% or higher. Also, Al may prevent the formation of carbides in ferrite similarly to Si such that Al may contribute to stabilizing residual austenite and may increase a bainite formation temperature. When a content of Al exceeds 0.2%, however, an A3 temperature may increase such that a high temperature annealing process may be inevitable, and it may be difficult to manufacture a preferable slab due to the reaction with mold flux during casting, and may also form surface oxides such that coatability may degrade. Thus, it may be preferable to limit a content of Al to 0.01 to 0.2%.

Nickel (Ni): 0.01 to 3.0%

[0030] Nickel is an element which may secure strength by solid solution strengthening and may stabilize austenite. It may be preferable to maintain 0.01% or higher of Ni. However, as Ni has a significant effect in delaying bainite transformation, when a content of Ni is excessive, bainite transformation may be incomplete such that FM may be formed. Thus, it may be preferable to limit an upper limit content of Ni to be 3%.

Molybdenum (Mo): 0.2% or less

[0031] Mo may be added because Mo may enhance strength by solid solution strengthening, and may refine a bainite structure by forming TiMo carbides. However, because of the problem of an increase of raw material costs as a price of alloy iron is high, it may be preferable to limit an upper limit content of Mo to 0.2%.

Titanium (Ti): 0.01 to 0.05%

[0032] As Ti may preferentially form TiN, Ti may need to be added to improve hardenability by addition of solid soluble boron. In the present disclosure, a lower limit content of Ti may be controlled to be 0.01% to preferentially form TiN before BN. When a content of Ti is excessive, TiN may be crystallized and may cause the blocking of a nozzle during continuous casting. Thus, it may be preferable to limit an upper limit content of Ti to be 0.05%.

Antimony (Sb): 0.02 to 0.05

[0033] Sb is a grain boundary segregation element, and may thus form grain boundary oxides. Thus, as a means for preventing decarburization through a grain boundary and for preventing degradation of zinc coatability caused by Mn, Si, and the like, enriched on a surface, it may be preferable to add 0.02% or higher of Sb. However, a content of Sb is excessive, the grain boundary segregation may increase, which may cause the brittleness of steel. Thus, an upper limit content of Sb may be limited to 0.05%.

Boron (B): 0.0005 to 0.003%

[0034] B is an inexpensive alloy element which may easily secure strength by quenching, and may be effective for reducing a total amount of alloy. B may also be advantageous to preventing weldability or high temperature brittleness. Thus, a lower limit content of B may be controlled to be 0.005%. When a content of B is excessive, a BN formation temperature may increase more than that of TiN, which may cause high temperature brittleness of steel. Thus, it may be preferable to limit an upper limit content of B to 0.003%.

Nitrogen (N): 0.01% or less

[0035] N may decrease an alloy efficiency of alloy elements by forming BN and TiN. Thus, it may be preferable to limit a content of N to 0.01% or less, a generally controllable range.

[0036] A remainder other than the above-described composition is Fe. However, in a general manufacturing process, inevitable impurities may be inevitably added from raw materials or a surrounding environment, and thus, impurities may not be excluded. A person skilled in the art may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure.

[0037] The cold-rolled steel sheet satisfying the above-described steel composition elements may have a microstructure including, by area fraction, bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less. Strength of bainite may be the second highest after martensite, and bainite may have intermediate properties between ferrite and martensite. Also, when fine residual austenite is distributed in a bainite phase, strength of steel and a ductility balance may significantly increase.

[0038] The cold-rolled steel sheet satisfying the above-described microstructure may have tensile strength of 980MPa or higher, and may provide a high-forming giga-grade high strength steel sheet having excellent yield strength and press formability and excellent ductility and hole expandability as compared to a steel sheet manufactured through a conventional Q&P heat treatment.

[0039] The present disclosure may also provide a hot-dip galvanized steel sheet manufactured by hot-dip zinc plating a surface of the cold-rolled steel sheet, and an alloyed hot-dip galvanized steel sheet manufactured by alloy hot-dip zinc plating the hot-dip galvanized steel sheet.

[0040] A method of manufacturing a cold-rolled steel sheet, and the like, of the present disclosure will be described in detail.

[0041] The cold-rolled steel sheet according to the present disclosure may be manufactured by reheating, hot-rolling, coiling, cold-rolling, and annealing a steel slab satisfying the above-described steel composition, and the processes may be as below.

(Reheating Steel Slab)

[0042] In the present disclosure, before performing a hot-rolling process, it may be preferable to perform a homogenization process by reheating the steel slab, and the process may be performed in a temperature range of 1000 to 1300°C preferably.

[0043] When a temperature during the reheating is lower that 1000°C, there may be the problem of a rapid increase of a rolling load. When the temperature exceeds 1300°C, energy costs may increase, and an amount of surface scale may become excessive. Thus, in the present disclosure, the reheating process may be performed at 1000 to 1300°C.

(Hot-Rolling Process)

[0044] The reheated steel slab may be hot-rolled and may be manufactured as a hot-rolled steel sheet. It may be preferable to perform a hot-finish-rolling process at 800 to 950°C.

[0045] When a rolling temperature during the hot-finish-rolling is lower than 800°C, a rolling load may greatly increase such that the rolling may be difficult. When the hot-finish-rolling temperature exceeds 950°C, heat fatigue of a roller may greatly increase, which may be a cause of reduction in life span. Thus, in the present disclosure, it may be preferable to limit the hot-finish-rolling temperature during the hot-rolling to 800 to 950°C.

(Coiling)

[0046] The hot-rolled steel sheet manufactured as above may be coiled. A coiling temperature may be 750°C or less preferably.

[0047] When the coiling temperature is too high during the coiling, a scale on a surface of the hot-rolled steel sheet may excessively occur, which may cause a surface defect and may become a cause of deterioration of coatibility. Thus, it may be preferable to perform the coiling at 750°C or lower. A lower limit content of the coiling temperature may not be particularly limited, but in consideration of a difficulty in performing a subsequent cold-rolling process caused by an excessive increase of strength of the hot-rolled steel sheet by the formation of martensite, it may be preferable to perform the coiling at Ms (a martensite transformation initiating temperature) to 750°C.

(Cold-Rolling)

[0048] The coiled hot-rolled steel sheet may be pickled and an oxide layer may be removed. Thereafter, a cold-rolling process may be performed to have a uniform shape and thickness of the steel sheet, thereby manufacturing a cold-rolled steel sheet.

[0049] Generally, the cold-rolling process may be performed to secure a thickness required by a customer. There may be no limitation in reduction ratio, but it may be preferable to perform the cold-rolling under a cold press reduction ratio of 30% or higher to prevent the formation of coarse ferrite grains in recrystallization during a subsequent annealing process.

(Q&P Continuous Annealing)

[0050] In the present disclosure, to manufacture the cold-rolled steel sheet having a final microstructure including bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less, a control of an subsequent annealing process may be important. Particularly, in the present disclosure, to secure a target microstructure from the partitioning of elements such as carbon, manganese, and the like, during annealing, a Q&P continuous annealing process may be selected after a general cold-rolling process, and QT and PT may be controlled depending on alloy elements as described below, which may be one of features of the present disclosure.

<u>Soaking and Rapidly Cooling</u>

[0051] The manufactured cold-rolled steel sheet may be soaked to an Ac3 temperature or higher for 30 seconds or longer, and the cold-rolled steel sheet may be cooled to a quenching temperature(QT)±10°C defined by Relational Expression 1 below at a cooling rate of 5 to 20°C/sec (see FIG. 1) preferably.

[0052] The processes may be performed as above to obtain a ferrite structure within 5% or less, which may be disadvantageous to hole expandability. In the present disclosure, a ferrite unformed cooling rate may be designed to be 5 to 20°C/sec. There may be no problem if the cooling rate is faster than the aforementioned cooling rate, but the slower the cooling rate, the more excellent the sheet shape may be without distortion, and thus, it may not be necessary to further increase the cooling rate.

[0053] As for QT, the cooling may be performed to a temperature in which 20 to 50% of martensite is formed. When martensite formed during quenching in the Q&P is reheated to a PT and partitioned, martensite may become tempered such that strength may degrade, and the formation of bainite may be facilitated. As illustrated in FIG. 2, when the partitioning processes are performed at the same temperature, in the case of TBF which may rapidly cool a steel sheet to a bainite region temperature and may isothermally maintain the steel sheet, the bainite precipitation was incomplete even after 600 seconds such that FM was formed, whereas, when sufficient martensite is formed, bainite transformation was completely performed even during a short period of time such that FM was not formed. Thus, in the present disclosure, the amount of FM may be controlled to be extremely low because, as elements such as carbon and manganese are enriched in austenite remaining during the bainite transformation, FM which may not remain as austenite but may be transformed during a final cooling process may have excessively high strength due to martensite including an excessively high amount of alloy elements, which may cause an interfacial separation during hole expansion such that cracks may easily be created, and hole expandability may greatly degrade.

[0054] In the present disclosure, the above-described properties were founded, and high-formability and high strength steel having a bainite main phase was developed considering the above-described properties. A QT in which the formation of bainite is facilitated and an area ratio of bainite becomes maximum was obtained as below through experiments.

[Relational Expression 1]

$$QT = 493.497 + 36.2874\times Al - 394.0\times C - 45.0\times Mn - 11.4332\times Mo - 20.8772\times Ni - 13.0438\times Si - 12.8\times Cr$$

Partitioning Heat Treatment

[0055] Thereafter, in the present disclosure, the cooled steel sheet may be reheated to a bainite temperature(PT)±10°C defined by Relational Expression 2 below, and the steel sheet may be maintained within a temperature range of QT≥ or ≥ QT-100°C for 100 seconds, and may be cooled.
[0056] After the quenching described above, in relation to reheating the steel sheet to a bainite temperature (PT) and isothermal maintaining the steel sheet, the temperature in which bainite is most early formed was obtained through experiments. When the temperature is higher than the obtained temperature, the amount of formed bainite may be low, and the stabilization of residual austenite may be incomplete such that the FM formation may rather increase. Thus, the steel sheet may need to be heated to PT±10°C.

[Relational Expression 2]

$$PT = 599.088 + 11.5214 \times Al - 225.2 \times C - 35.0 \times Mn -$$

[0057] Differently from the prior art, in the present disclosure, it may not be necessary to maintain the steel sheet at a constant temperature in the isothermal maintaining. In the isothermal maintaining, the steel sheet may be maintained within a temperature range of QT≥ or ≥ QT-100°C for 100 seconds, and may be cooled. Thus, the method may easily be applied to a facility having an isothermal maintaining furnace without a heating maintaining apparatus, which may be an advantage of the present disclosure.
[0058] When the Q&P heat treatment is performed as above, steel including bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less may be manufactured, and by extremely reducing ferrite and FM which has significantly different strengths, a high-forming giga-grade high strength steel sheet having excellent yield strength, ductility, and hole expandability may be manufactured as compared to a steel sheet manufactured through a conventional Q&P heat treatment.

(Plating)

[0059] A plated steel sheet may be manufactured by plating the cold-rolled steel sheet on which the primary and secondary annealing heat treatment processes were performed. The plating process may be performed using a hot-dip plating method or an alloying hot-dip plating method, and the plating layer formed through the method may be a zinc-based plated layer preferably.
[0060] When the hot-dip plating method is used, the steel sheet may be submerged in a zinc plating bath and may be manufactured as a hot-dip plated steel sheet, and as for the alloying hot-dip plating method also, an alloy hot-dip galvanized steel sheet may be manufactured by performing a general alloying hot-dip plating process.

[Mode for Invention]

[0061] In the description below, the present disclosure will be described in detail in accordance with an embodiment.

(Embodiment)

[0062] A hot-dip metal having an element composition as indicated in Table 1 was manufactured as an ingot having a thickness of 90mm and a width of 175mm through vacuum melting. The ingot was reheated at 1200°C for 1 hour, was homogenized, and was hot-finish-rolled at 900°C or higher, higher than Ar3, thereby manufacturing a hot-rolled steel sheet. The hot-rolled steel sheet was cooled, was charged to a furnace heated in advanced to 600°C and was maintained for 1 hour, and was furnace-cooled, thereby stimulating a hot-rolling coiling process. The hot-rolled sheet material as above was cold-rolled under a cold press reduction ratio of 50 to 60%, and an annealing heat treatment was performed under conditions as in Table 2 below, thereby manufacturing a final cold-rolled steel sheet.
[0063] A structure fraction, yield strength, tensile strength, an elongation rate, and HER of each of the cold-rolled steel sheets manufactured as above were measured, and the results were listed in Table 2 below as well.

[Table 1]

	C	Mn	Si	Al	Cr	Ni	Mo	Ti	Sb	B	N
Inventive Steel A	0.1	2.2	1.4	0.02	0.6	0.02	0.04	0.017	0.027	0.0021	0.005
Inventive Steel B	0.14	1.9	1.4	0.03	0.5	0.02	0.04	0.021	0.04	0.0017	0.003
Inventive Steel C	0.18	2.5	0.6	0.02	1.1	0.02	0.05	0.014	0.021	0.0012	0.004
Inventive Steel D	0.16	2.1	1.9	0.04	0.3	0.02	0.05	0.022	0.035	0.0023	0.006

Inventive Steel E	0.09	2.2	1.4	0.15	0.6	0.02	0.06	0.031	0.027	0.0018	0.005
Inventive Steel F	0.13	1.8	1.3	0.02	0.4	2	0.02	0.027	0.032	0.0017	0.004
Inventive Steel G	0.08	2.5	1.3	0.06	0.3	0.03	0.18	0.019	0.041	0.0024	0.005
Comparative Steel H	0.05	2.1	1.6	0.02	0.45	0.06	0.05	0.015	0.03	0.0017	0.003
Comparative Steel I	0.18	1.8	0.21	0.02	0.28	0.02	0.04	-	0.04	-	0.005
Comparative Steel J	0.08	1	1.3	0.04	0.9	0.02	0.02	0.012	0.02	0.0011	0.004

Comparative Steel K	0.17	2.2	1.3	0.25	0.3	0.02	0.05	0.027	0.04	0.0018	0.004
Comparative Steel L	0.18	1.6	1.5	0.02	1.6	3.5	0.05	0.032	0.021	0.0013	0.005

[Table 2]

	Steel	Manufacturing Method	Annealing	QT	PT	YS	TS	El	HER	B	TM	FM	A	F
Inventive Example	A	1	850	330	450	721	1017	18.1	71.1	75	15	2	8	0
	B	2	850	330	450	771	1043	16.5	65.3	65	25	4	6	0
	C	3	850	290	430	1076	1235	12.1	56.6	68	21	6	5	0
	D	4	850	310	430	830	1180	14.5	72.6	72	15	4	9	0
	E	5	870	340	450	654	983	17.3	71.4	75	14	5	6	0
	F	6	850	300	430	818	1060	16.7	70.2	62	20	9	9	0
	G	7	850	330	450	987	1220	13.6	64.6	76	13	6	5	0
Comparative	H	8	850	350	460	395	794	21	71.6	28	15	18	7	32
	I	9	850	340	480	898	995	10.4	66.6	61	18	21	0	0
	J	10	850	390	490	321	686	26.4	43.2	13	12	11	13	51
	K	11	850	310	450	640	1155	11.2	38.7	32	7	25	6	30
	L	12	850	240	360	674	1288	9.8	24.7	65	15	16	4	0
	B	13	850	330	450	475	894	23.1	17.6	59	11	21	9	0
	E	14	820	340	450	540	870	21.2	24.6	23	0	9	16	52
	G	15	850	330	450	523	910	18.9	27.3	61	5	23	11	0

* In table 2 above, B is bainite, TM is tempered martensite, FM is fresh martensite, A is residual austenite, and F is ferrite.

[0064] As indicated in Table 1 above, inventive examples A to G of which the steel composition and also the manufacturing processes satisfied the ranges of the present disclosure had excellent yield strength, ductility, and hole expandability.

[0065] FIG. 3 is an image of a microstructure of inventive example (F) steel manufactured by the present disclosure. As indicated in Table 2, inventive example (F) steel may manufacture bainite steel in which bainite was 75% as a main phase, TM and FM were 14% and 5%, respectively, TM/FM ratio exceeding 2, and F was 5% or less, which is a technical feature of the present disclosure. Conventionally, TRIP steel of a ferrite matrix was manufactured through a Q&P heat treatment, or mainly tempered martensite steel was manufactured. However, when a steel alloy composition, QT, and PT are specified as in the present disclosure, a bainite matrix structure may easily be manufactured than by using a TBF heat treatment method.

[0066] FIG. 4 is an observation of TM in the structure in FIG. 3 using an APT. As show in FIG. 4, transition carbides and coarse cementite were mixed, the structure was tempered martensite.

[0067] As for comparative examples H to L, B,E, and G of which the alloy compositions and the manufacturing processes were beyond the ranges of the present disclosure, yield strength, ductility, and hole expandability were poor as compared to the inventive examples.

[0068] Particularly, as indicated in Table 2, in comparative examples B, E, and G of which the alloy compositions satisfied the ranges of the present disclosure but the manufacturing processes did not satisfy the present disclosure, intended properties were not obtained.

[0069] FIG. 5 is a structure of comparative example (E) steel. The structure had the same composition as in the present disclosure, but due to two-phase region annealing and a TBF heat treatment, ferrite and FM were formed such that strength and HER were low.

[0070] According to the results described above, as the cold-rolled steel sheet manufactured according to the present disclosure may secure yield strength of 980MPa or higher and an excellent elongation rate and HER, there may be an advantage in that a cold press forming process for applying the steel sheet to a structural member may easily be performed as compared to a steel material manufactured through a conventional Q&P heat treatment process.

[0071] While exemplary embodiments have been shown and described above, the scope of the present disclosure is not limited thereto, and it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present invention as defined by the appended claims.

Claims

1. A high strength cold-rolled steel sheet having excellent yield strength, ductility, and hole expandability, comprising:by wt%, 0.06 to 0.2% of carbon (C), 1.5 to 3.0% of manganese (Mn), 0.3 to 2.5% of silicon (Si), 0.01 to 0.2% of aluminum (Al), 0.01 to 3.0% of nickel (Ni), 0.2% or less of molybdenum (Mo), 0.01 to 0.05% of titanium (Ti), 0.02 to 0.05% of antimony (Sb), 0.0005 to 0.003% of boron (B), 0.01% or less of nitrogen (N), excluding 0, and a balance of Fe and inevitable impurities,
wherein a microstructure thereof comprises, by area fraction, bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less.

2. The high strength cold-rolled steel sheet of claim 1, wherein a TM/FM ratio exceeds 2.

3. A hot-dip galvanized steel sheet, manufactured by hot-dip zinc plating a surface of the cold-rolled steel sheet of claim 1.

4. An alloyed hot-dip galvanized steel sheet, manufactured by alloy hot-dip zinc plating a surface of the cold-rolled steel sheet of claim 1.

5. A method of manufacturing a high strength cold-rolled steel sheet having excellent yield strength, ductility, and hole expandability, the method comprising:

   reheating a steel slab comprising by wt%, 0.06 to 0.2% of carbon (C), 1.5 to 3.0% of manganese (Mn), 0.3 to 2.5% of silicon (Si), 0.01 to 0.2% of aluminum (Al), 0.01 to 3.0% of nickel (Ni), 0.2% or less of molybdenum (Mo), 0.01 to 0.05% of titanium (Ti), 0.02 to 0.05% of antimony (Sb), 0.0005 to 0.003% of boron (B), 0.01% or less, excluding 0, of nitrogen (N), and a balance of Fe and inevitable impurities, hot-rolling the steel slab, and performing a coiling process; and
   cold-rolling and continuously Q&P annealing the coiled hot-rolled steel sheet,
   wherein the continuous Q&P annealing comprises:

soaking the manufactured cold-rolled steel sheet to an Ac3 temperature or higher for 30 seconds or longer, and cooling the cold-rolled steel sheet to a quenching temperature(QT)±10°C defined by Relational Expression 1 below at a cooling rate of 5 to 20°C/sec,

[Relational Expression 1]

$$QT = 493.497 + 36.2874\times Al - 394.0\times C - 45.0\times Mn - 11.4332\times Mo - 20.8772\times Ni - 13.0438\times Si - 12.8\times Cr;$$

reheating the cooled steel sheet to a bainite temperature(PT)±10°C defined by Relational Expression 2 below, maintaining the steel sheet within a temperature range of QT≥ or ≥ QT-100°C for 100 seconds, and cooling the steel sheet,

[Relational Expression 2]

$$PT= 599.088 + 11.5214\times Al - 225.2\times C - 35.0\times Mn - 19.9474\times Ni - 24.9385\times Si - 56.718\times Mo - 22.1\times Cr.$$

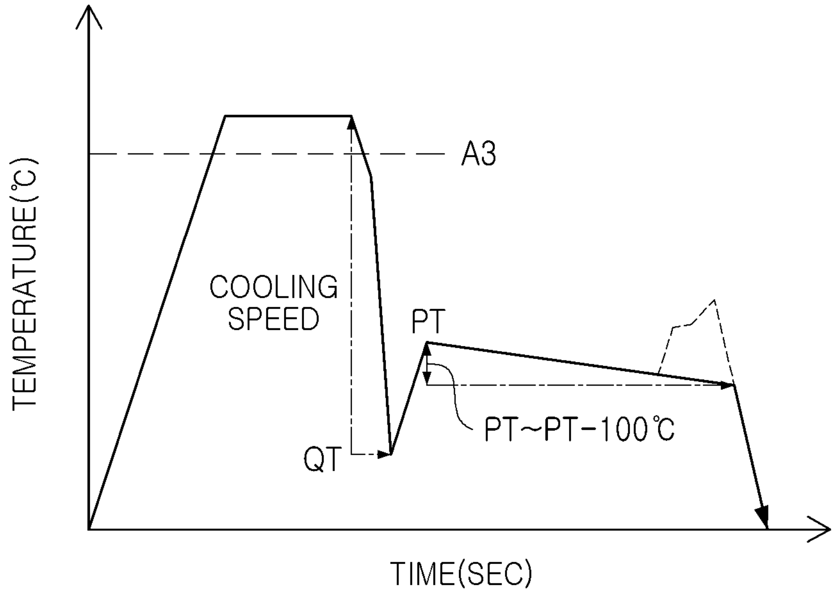
6. The method of claim 5, wherein the steel sheet after the continuous Q&P annealing has a microstructure including, by area fraction, bainite of 50% or higher, tempered martensite (TM) of 10% or higher, fresh martensite (FM) of 10% or less, residual austenite of 20% or less, and ferrite of 5% or less.

7. The method of claim 6, wherein a TM/FM ratio exceeds 2.

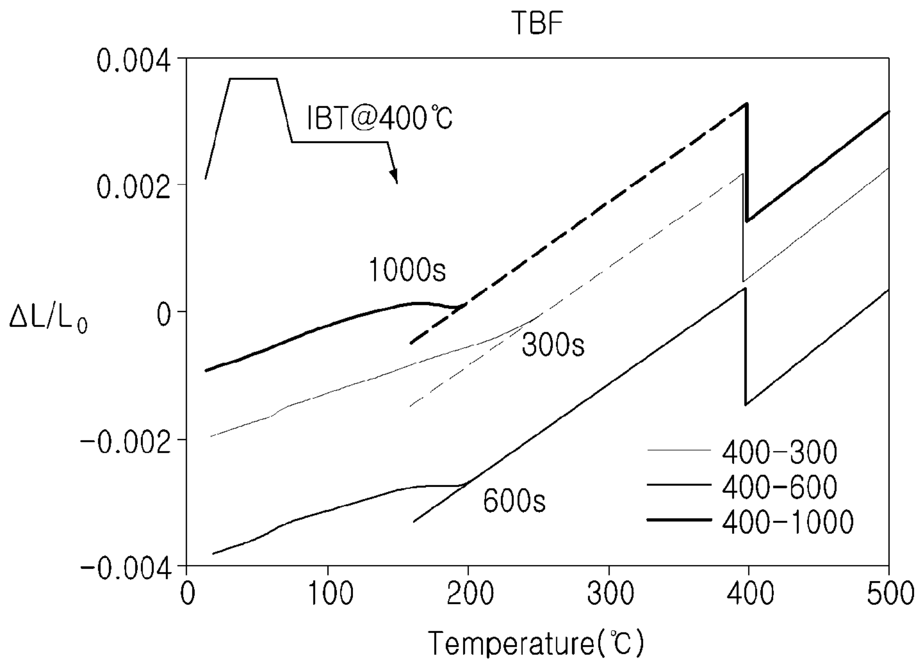
8. A method of manufacturing a hot-dip galvanized steel sheet having excellent yield strength, ductility, and hole expandability, the method comprising:
hot-dip zinc plating a surface of the continuously Q&P annealed cold-rolled steel sheet of claim 5.

9. A method of manufacturing an alloyed hot-dip galvanized steel sheet having excellent yield strength, ductility, and hole expandability, the method comprising:
alloy hot-dip zinc plating a surface of the continuously Q&P annealed cold-rolled steel sheet of claim 5.

【Fig. 1】



【Fig. 2】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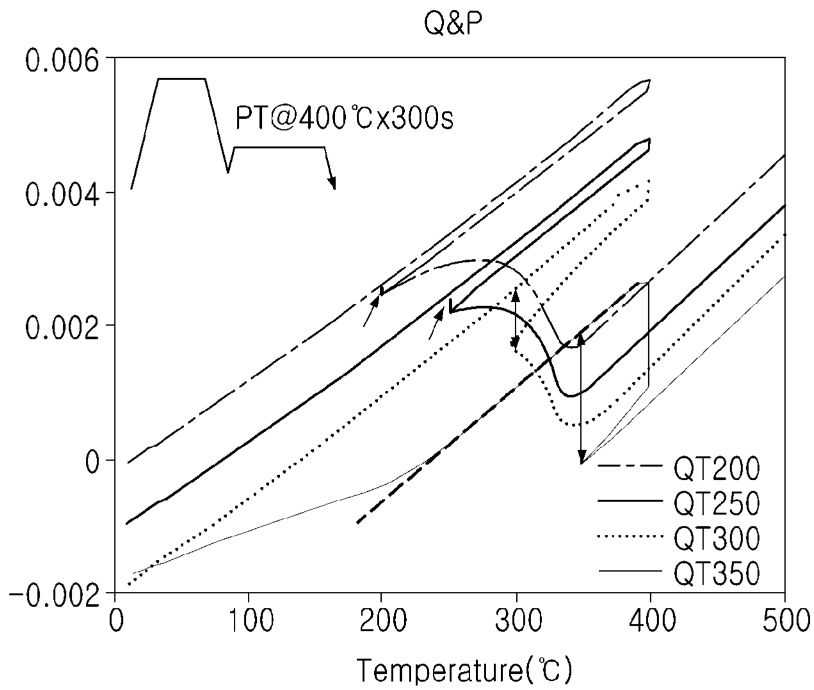
400
500
Temperature(℃)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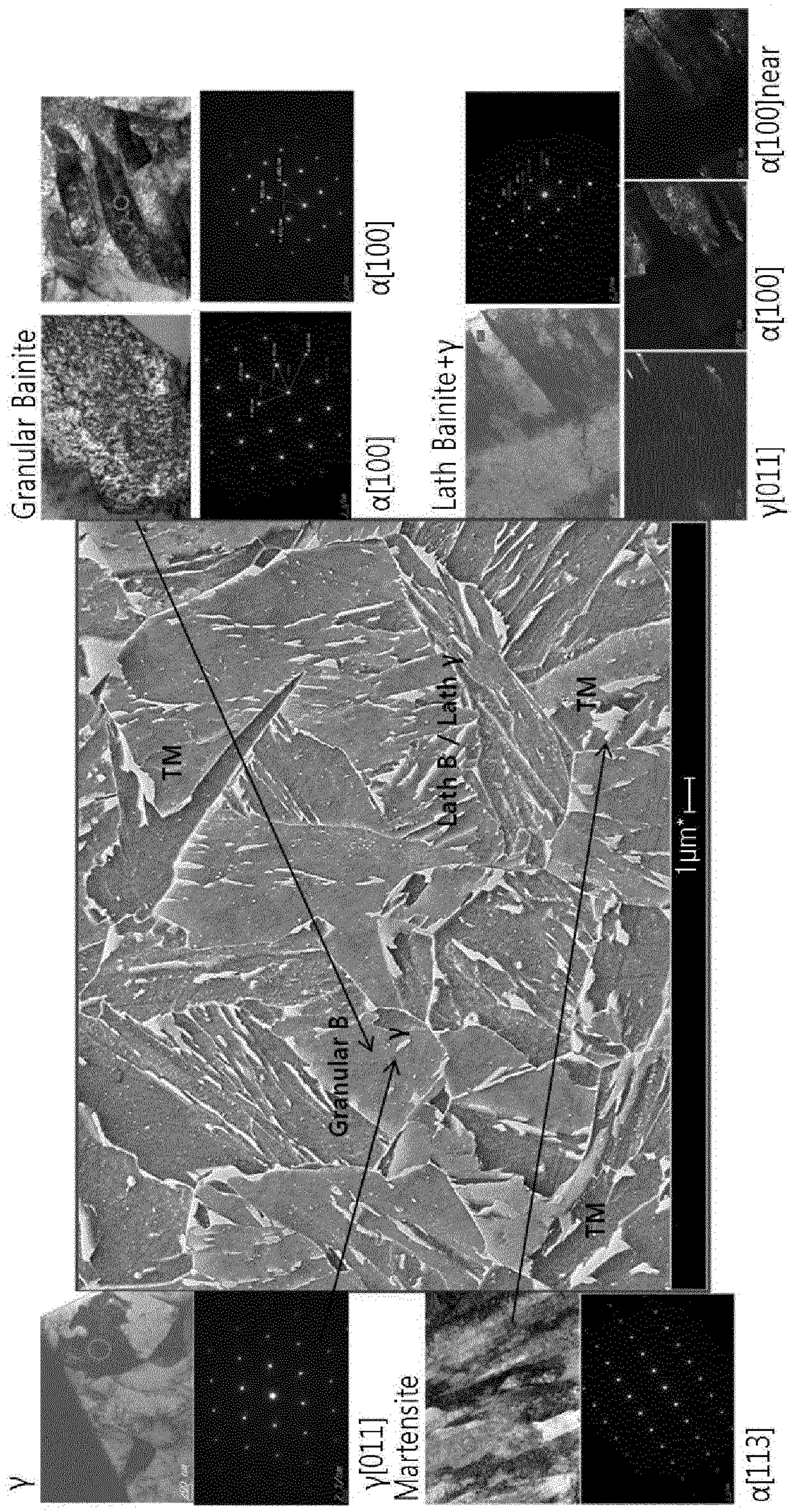
Temperature(℃)

【Fig. 3】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α[100]
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γ[011]
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TM
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γ
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Martensite
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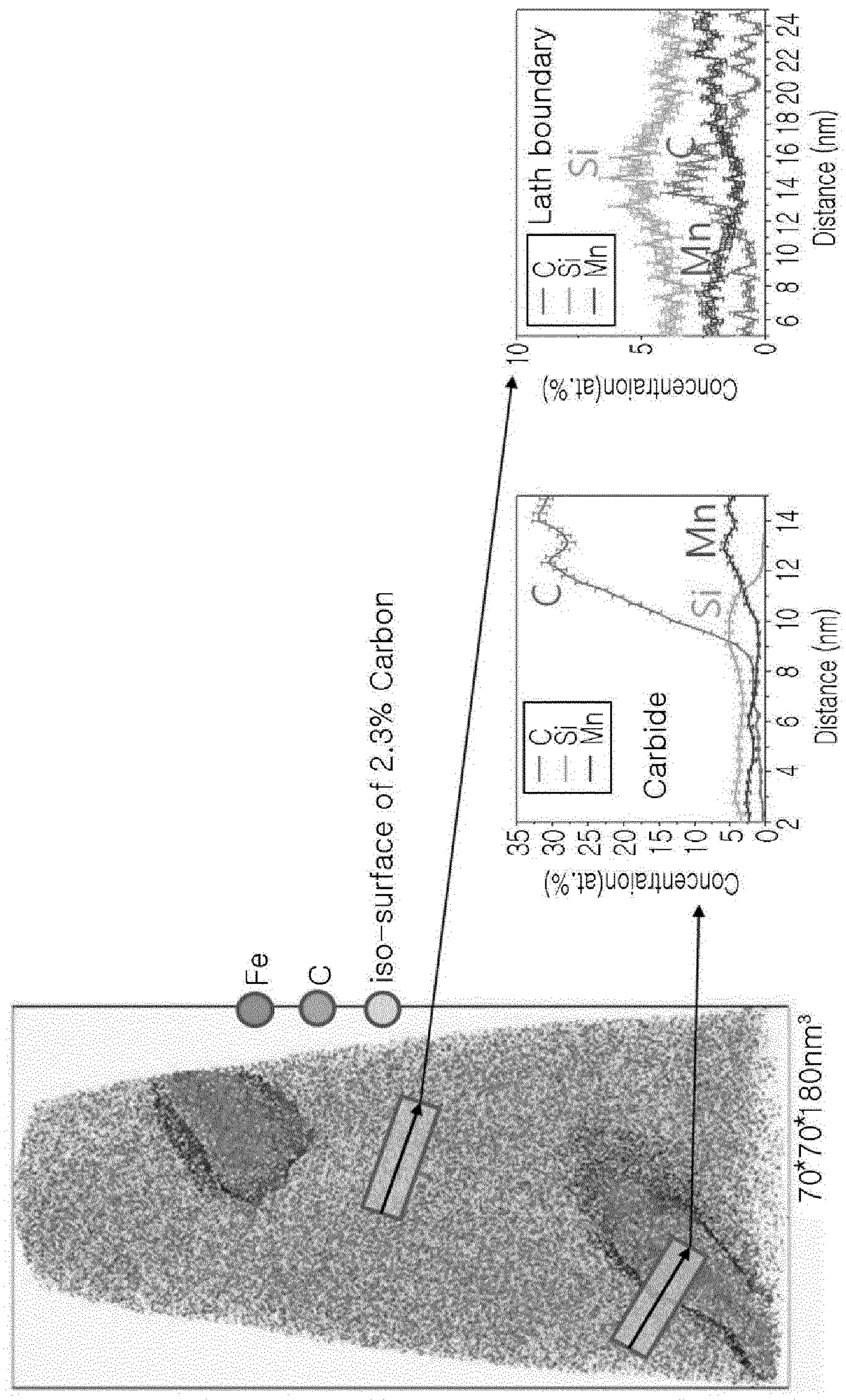
【Fig. 4】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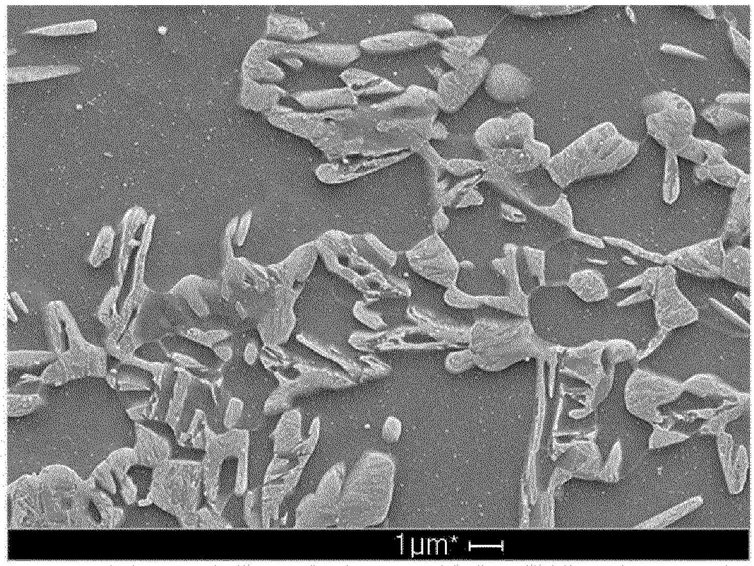
Lath boundary
Concentraion(at.%)
Distance (nm)

【Fig. 5】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/013762

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/60(2006.01)i, C22C 38/58(2006.01)i, C22C 38/02(2006.01)i, C22C 38/06(2006.01)i, C22C 38/44(2006.01)i, C22C 38/50(2006.01)i, C22C 38/54(2006.01)i, C23C 2/06(2006.01)i, C21D 8/02(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)

C22C 38/60; C21D 9/46; C22C 38/06; C21D 8/02; C22C 38/00; C22C 38/58; C22C 38/02; C22C 38/44; C22C 38/50; C22C 38/54; C23C 2/06

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: antimony, high strength cold rolled steel sheet, tempered martensite, fresh martensite, Q&P continuous annealing process

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2016-0132926 A (KABUSHIKI KAISHA KOBE SEIKO SHO (KOBE STEEL, LTD.)) 21 November 2016 See paragraphs [0064], [0132]-[0134]; claims 1-8; and figure 1.	1-4
A		5-9
A	KR 10-2015-0130612 A (POSCO) 24 November 2015 See paragraphs [0024]-[0096]; and figures 1-4.	1-9
A	KR 10-2016-0060729 A (KABUSHIKI KAISHA KOBE SEIKO SHO (KOBE STEEL, LTD.)) 30 May 2016 See claims 1-8; and figures 1, 2a-2b, 3-6.	1-9
A	JP 2014-034716 A (NIPPON STEEL & SUMITOMO METAL) 24 February 2014 See paragraphs [0014]-[0060]; and tables 1-3.	1-9
A	JP 2011-140686 A (SUMITOMO METAL IND., LTD.) 21 July 2011 See paragraphs [0021]-[0078]; and tables 1-3.	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
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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
02 MARCH 2018 (02.03.2018)	**05 MARCH 2018 (05.03.2018)**

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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2017/013762

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- *ISIJ International,* 2011, vol. 51, 137-144 **[0010]**