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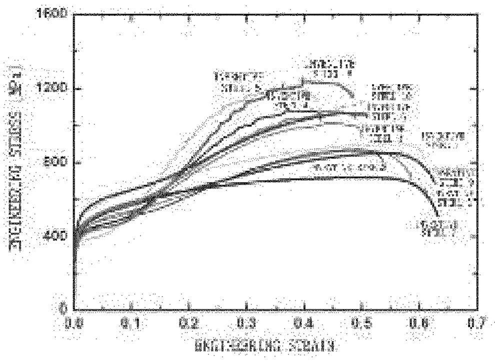
(54) LOW ALLOY STEEL SHEET HAVING EXCELLENT STRENGTH AND DUCTILITY

(57) The present invention minimizes the addition of alloying elements to reduce surface cracking during hot rolling, ensures corrosion resistance by constituting Cr as one of the main components, and realizes a TRIP or TWIP phenomenon through a high Mn design, thereby providing a low alloy steel sheet with excellent hot workability, strength and ductility. The low alloy steel sheet excellent in strength and ductility according to an embodiment of the present invention comprises, in percent (%) by weight of the entire composition, 0.05 to 0.3 % of carbon (C), 0.7 to 2.5 % of silicon (Si), 8 to 12 % of manganese (Mn), 13 to 15.5 % of chromium (Cr), 0.5 to 3.0 % of copper (Cu), 0.1 to 0.2 % of nitrogen (N), 0.25 % or less of aluminum (Al), 0.25 % or less of tin (Sn), and the remainder of iron (Fe) and other inevitable impurities. The microstructure of the low alloy steel sheet comprises at least one of a ferrite phase and a martensite phase at a volume fraction of 5% or less, and the remainder includes an austenite phase.

FIG. 15



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Description

[Technical Field]

[0001] The present disclosure relates to a high strength and high ductility steel sheet suitable for structural materials such as automobiles and railroad tracks and more particularly, the present invention relates to a low alloy steel sheet excellent in strength and ductility by minimizing alloying elements such as Ni and controlling a microstructure with Cr and Mn as main components, and a method of manufacturing the same.

[Background Art]

[0002] High strength and high ductility steel sheets have been used continuously to reduce the weight of automobile bodies. In recent years, transformed structure steel excellent in processability compared to existing precipitation strengthening or solid solution strengthening steels has been developed and used. The transformed structure steel is represented by DP (Dual Phase) steel, TRIP (TRansformation Induced Plasticity) steel and CP (Complex Phase) steel. The mechanical properties of the transformed structure steel such as the tensile strength and the elongation level are changed depending on the shape of the parent phase and the type and the fraction of the second phase, respectively.

[0003] The TRIP steel, which is one of the transformed structure steels, can control both the cooling rate and the cooling termination temperature during the cooling process after forming austenite during the annealing process, thereby partially improving the strength and ductility by partially retaining the austenite at room temperature.

[0004] The metastable retained austenite is transformed into martensite by deformation, thereby increasing elongation by delaying local stress concentration relaxation and necking with increasing strength. Therefore, it is important that the TRIP steels retain austenite more than a certain fraction at room temperature. For this purpose, an austenite stabilizing element should be added together with a large amount of Mn to maintain a certain percentage of the retained austenite at room temperature.

[0005] On the other hand, there is TWIP (Twinning Induced Plasticity) steel which constitutes an austenite single phase by adding a large amount of C and Mn in the steel in addition to the above transformed textured steel. In the case of the TWIP steel, it exhibits excellent tensile strength and elongation. However, when the content of C in the TWIP steel is 0.4% by weight, the austenite causing a twinning phenomenon cannot be stably obtained unless the content of Mn is about 25% by weight or more. And also, when the content of C in the TWIP steel is 0.6% by weight, the austenite cannot be stably obtained unless the content of Mn is about 20% by weight or more. Also, a large amount of an austenite stabilizing element should be added so that austenite can stably exist at room temperature because epsilon martensite (ε) of an HCP structure and martensite (a ') of a BCT structure are formed which are extremely detrimental to workability.

[0006] PCT Published Patent Application No. 2012/077150 relates to high Mn-containing TWIP steels having excellent mechanical properties and moldability, and includes cold rolling annealed steel for cold annealing and recrystallization heat treatment. In this patent document, alloying elements such as C, Al and Si are additionally added to stabilize the austenite phase or to control the stacking defect energy (SFE).

[0007] As described above, the TRIP steel and the TWIP steel to which a large amount of the alloy component is added are solidified into an austenite single phase at the time of manufacture and hot workability is weakened, and a defect caused by inclusions such as Al easily occurs in hot rolling. There is a disadvantage in that manufacturing technology such as a casting and a rolling process is very difficult due to a problem, and the manufacturing cost is high due to a large increase in the alloy cost.

[0008] (Patent Document 0001 PCT Published Patent Publication No. 2012-077150 (June. 14, 2016)

[Disclosure]

[Technical Problem]

[0009] The present invention minimizes the addition of alloying elements to reduce surface cracking during hot rolling, ensures corrosion resistance by constituting Cr as one of the main components, and realizes a TRIP or TWIP phenomenon through a high Mn design, thereby providing a low alloy steel sheet with excellent hot workability, strength and ductility.

[Technical Solution]

[0010] In accordance with an aspect of the present disclosure, a low alloy steel sheet excellent in strength and ductility comprises, , in percent (%) by weight of the entire composition, 0.05 to 0.3 % of carbon (C), 0.7 to 2.5 % of silicon (Si), 8 to 12 % of manganese (Mn), 13 to 15.5 % of chromium (Cr), 0.5 to 3.0 % of copper (Cu), 0.1 to 0.2 % of nitrogen (N), 0.25 % or less of aluminum (Al), 0.25 % or less of tin (Sn), and the remainder of iron (Fe) and other inevitable impurities, wherein the microstructure of the low alloy steel sheet comprises at least one of a ferrite phase and a martensite phase at a volume fraction of 5% or less, and the remainder includes an austenite phase.

[0011] The low alloy steel sheet may further comprise 0.2% or less of nickel (Ni).

[0012] The low alloy steel sheet may further comprise 0.2% or less of molybdenum (Mo).

[0013] The elongation of the low alloy steel sheet may be 40% or more.

[0014] The tensile strength of the low alloy steel sheet may be 650 MPa or more.

[Advantageous Effects]

[0015] The low alloy steel sheet excellent in strength and ductility according to the embodiments of the present invention has a tensile strength of 650 MPa or more and an elongation of 40% or more by realizing a TRIP or TWIP phenomenon, and can be used for automobile parts or other structural materials .

[0016] Further, according to the embodiments of the present disclosure, the low alloy steel sheet includes Cr as one of the main components and has excellent corrosion resistance, minimizes the addition of alloying elements, and is excellent in hot workability.

[Description of Drawings]

[0017]

FIG. 1 to 4 are photographs showing the degree of occurrence of edge cracks in the hot rolling of inventive steels and comparative steels according to an embodiment of the present invention.

FIGS. 5 to 10 are optical micrographs of microstructures of inventive steels and comparative steels after hot annealing according to an embodiment of the present invention.

FIGS. 11 to 14 are optical micrographs showing microstructure changes according to the hot rolled annealing temperature of inventive steel 9 according to an embodiment of the present invention.

FIG. 15 is a graph showing tensile test results of inventive steels and comparative steels according to an embodiment of the present invention.

[Best Mode]

[0018] A low alloy steel sheet excellent in strength and ductility according to an embodiment of the present disclosure, may comprise, in percent (%) by weight of the entire composition, 0.05 to 0.3 % of carbon (C), 0.7 to 2.5 % of silicon (Si), 8 to 12 % of manganese (Mn), 13 to 15.5 % of chromium (Cr), 0.5 to 3.0 % of copper (Cu), 0.1 to 0.2 % of nitrogen (N), 0.25 % or less of aluminum (Al), 0.25 % or less of tin (Sn), and the remainder of iron (Fe) and other inevitable impurities. The microstructure of the low alloy steel sheet may comprise at least one of a ferrite phase and a martensite phase at a volume fraction of 5% or less, and the remainder includes an austenite phase.

[Modes of the Invention]

[0019] Hereinafter, the embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The following embodiments are provided to transfer the technical concepts of the present disclosure to those of ordinary skill in the art. However, the present disclosure is not limited to these embodiments, and may be embodied in another form. In the drawings, parts that are irrelevant to the descriptions may be not shown in order to clarify the present disclosure, and also, for easy understanding, the sizes of components are more or less exaggeratedly shown.

[0020] A low alloy steel sheet excellent in strength and ductility according to an embodiment of the present invention comprises, in percent (%) by weight of the entire composition, 0.05 to 0.3 % of carbon (C), 0.7 to 2.5 % of silicon (Si), 8 to 12 % of manganese (Mn), 13 to 15.5 % of chromium (Cr), 0.5 to 3.0 % of copper (Cu), 0.1 to 0.2 % of nitrogen (N), 0.25 % or less of aluminum (Al), 0.25 % or less of tin (Sn), and the remainder of iron (Fe) and other inevitable impurities.

[0021] The role and content of each component included in the low alloy steel sheet excellent in strength and ductility according to the present invention will be described below. Hereinafter, % refers to% by weight.

C: 0.05 to 0.3 %

[0022] Carbon is an austenite-forming element and is an effective element for increasing the strength of materials by solid solution strengthening. Although it is advantageous to add a large amount of C in order to secure high strength, the corrosion resistance is lowered when it is added in excess, thus the upper limit is limited to 0.3%. On the other hand, the lower limit is limited to 0.05% in order to take into consideration the decarburization load during smelting and to obtain the effect of increasing the strength by the minimum amount of C. It is preferable to add C in the range of 0.05 to 0.3% in order to ensure stable production and strength by the addition of C.

Si: 0.7 to 2.5 %

[0023] Silicon is partially added because it has a deoxidizing effect and is a ferrite stabilizing element. However, if it is excessive, the mechanical properties related to corrosion resistance and impact toughness will be deteriorated. When a large amount of Si is added, the ferrite content is increased to cause surface cracking during hot rolling, and there is a problem that the rolling load is increased during manufacture, thus the upper limit is limited to 2.5%. On the other hand, the lower limit is limited to 0.7% in order to control the stability of the austenite phase by the addition of Si, control strain-induced martensite formation, and ease production. For controlling the phase fraction by the addition of Si and controlling the deformation mechanism during the austenite phase transformation, it is preferable to limit the range of Si to 0.7 to 2.5%.

Mn: 8 to 12 %

[0024] Manganese is an austenite-forming element and is a major element constituting the austenite phase in the Cr-added steel. In particular, Cu is used as a substitute element for Ni. When Mn is contained in a large amount at the time of production, oxide-based inclusions cause defects in production or deterioration in corrosion resistance. An additional technique such as special refining to reduce the dissolved oxygen, is required for the inclusion reduction, and the manufacturing cost is increased. Therefore, the upper limit is limited to 12%. The minimum amount for the addition of Ni and the minimum amount for securing the austenite single phase or some of the ferrite or martensite structure is about 8%. Therefore, the range of Mn is preferably limited to 8 to 12%.

Cr: 13.0 to 15.5 %

[0025] Chromium is a representative ferrite-forming element and is an element that increases corrosion resistance. In particular, it is an element that greatly affects nitrogen solubility. In order to minimize surface cracking during hot rolling, it is preferable to control the initial phase at the time of solidification with ferrite so as not to control the trace elements, particularly S and P which are intergranular segregated elements, at a very low level. When the amount of ferrite exceeds a certain amount, it is present in two phases of ferrite and austenite at a high temperature, resulting in deterioration of hot workability and a large amount of cracks are generated in hot rolling. In addition, some of the ferrite phases are present more than necessary in the manufacture of the final product, resulting in deterioration of mechanical properties. Therefore, the upper limit of Cr is limited to 15.5%. On the other hand, when the content of Cr is too low, there is a problem of controlling the amount of P and S which are intergranular segregation sources by solidification at the austenite initial phase at the time of solidification at high temperature. If the above-mentioned control is insufficient, a large amount of surface cracks will occur during manufacture. In addition, at least 13.0% of chromium is required to have the minimum corrosion resistance and superior corrosion resistance to carbon steel. Therefore, it is preferable that the content of Cr is limited to 13.0 to 15.5% in order to solidify the initial phase into ferrite within the range of the desired alloying element and to maintain the corrosion resistance of the minimum stainless steel level.

Cu: 0.5 to 3.0 %

[0026] Copper is an austenite-forming element similar to Mn and Ni. Cr is an element to be added in place of Ni, and when it is added in excess, it is precipitated in Cu in excess of solubility, resulting in grain boundary embrittlement upon heating. Therefore, the maximum content of Cr that can control the stability of austenite without exceeding the solubility is 3.0%. On the other hand, the minimum content of Cr is 0.5%. When the amount is less than that, the effect of the addition of Cu saturates and it does not affect the austenite stability and formation. Therefore, it is preferable that Cu is limited to 0.5 to 3.0%.

N: 0.1 to 0.2 %

[0027] Nitrogen is a representative austenite forming element together with Ni and it is an element which improves the corrosion resistance of the material together with Cr and Mo. The minimum N content of which the effect of the addition of N is shown and improves the strength of the material with interstitial elements together with C is 0.1 %. In general, pressure is applied to increase the solubility of N in order to dissolve a large amount of N in the material. Even if Cr and Mn, which are representative elements for increasing the solubility of N, are present in a large amount, the amount that can maximally dissolve N without applying atmospheric pressure is 0.2%. Therefore, it is preferable that the appropriate amount of N is limited within the range of 0.1 to 0.2%.

Al: 0.25 % or less

[0028] Aluminum is a ferrite-forming element in Cr-added stainless steel and is a useful element for deoxidation in steelmaking. At the same time, it is known that Al increases the stacking defect energy of the austenite phase to form strain-induced martensite or mechanical twinning at the time of modification, and improves a delayed fracture resistance, which is a crack generated after molding. If the Al content exceeds 0.25%, large Al-based inclusions are generated and cause surface defects. In addition, when Al is added excessively, it contains a large amount of ferrite phase at high temperature, which causes cracking during hot rolling. Therefore, the content of Al is limited to 0.25%.

Sn: 0.25 % or less

[0029] Tin is known as an element improving the corrosion resistance of the material and improving the pickling property by controlling the thickness of the annealing scale during annealing. That is, when Sn is added, the effect of suppressing the formation of SiO_2 oxide on a scale surface layer generated in the cold rolling or hot rolling annealing process can be increased and the efficiency of the cold rolling annealing process can be increased. However, the excessive addition of Sn causes deterioration in hot workability and a reduction in the production process, thus the upper limit is limited to 0.05%. In addition, in the case of the corrosion resistance, when Sn is added, Sn is added to the surface of a passivation layer of the stainless steel to increase the resistance of the coating. Therefore, the content of Sn is limited to a range of 0.05%.

[0030] According to an embodiment of the present invention, the low alloy steel sheet may further contain 0.2% or less of Ni and / or 0.2% or less of Mo in % by weight.

[0031] Nickel is an austenite-forming element and plays the same role as Mn. Most of Ni is replaced with Mn, and some of nickel is present as impurities such as scrap. The residual amount of Ni is limited to 0.2%.

[0032] Molybdenum is an expensive element that increases the corrosion resistance and forms ferrite. The content of Mo is limited to 0.2%.

[0033] The low alloy steel sheet according to the present invention satisfying the alloy element composition range has at least one of a ferrite phase and a martensite phase in a microstructure at a volume fraction of 5% or less and the remainder includes an austenite phase. In addition, the low alloy steel sheet according to the present invention may contain an inevitable precipitate phase other than the ferrite phase and the martensite phase, but the sum of the volume fractions thereof is 5% or less.

[0034] The low alloy steel sheet according to the present invention can be manufactured through reheating of a slab, hot rolling, hot rolling annealing, pickling or the like according to a conventional manufacturing method for the molten steel satisfying the above-mentioned component system.

[0035] For example, the slab can be hot rolled at a normal rolling temperature, and the hot rolled steel sheet can be annealed at 900 to 1,200 ° C for 10 to 60 minutes. Thereafter, the hot rolled steel sheet can be cold-rolled by a conventional method to be made into a thin sheet. The low alloy steel sheet excellent in strength and ductility according to an embodiment of the present invention can be used, for example, in a general product for molding, and can be used as a strip, a bar, a plate, a sheet, a pipe, or a tube.

[0036] Hereinafter, the present invention will be described in detail with reference to the following examples. However, the following examples are intended to illustrate the present invention in more detail, but the scope of the present invention is not limited to these examples.

Examples

[0037] Specimens of steels corresponding to the composition range of the composition according to the present invention were prepared, and the phase fraction, elongation, and tensile strength of the material were measured after hot rolling and hot rolled annealing. Table 1 below shows the alloy composition (wt%) for the experimental steel types.

[Table 1]

	C	Si	Mn	Cr	Cu	N	Ni	Mo	Al	Sn
Inventive Steel 1	0.078	1.98	10.3	14.1	2.05	0.134	0	0.100	-	-
Inventive Steel 2	0.080	2.02	8.2	13.9	2.03	0.144	0	0	-	-
Inventive Steel 3	0.080	1.03	8.9	13.9	2.00	0.157	0.100	0.1	-	-
Inventive Steel 4	0.078	1.00	9.0	14.1	1.00	0.149	0.060	0.1	-	-
Inventive Steel 5	0.079	2.01	9.0	14.0	0.51	0.146	0.120	0	-	-
Inventive Steel 6	0.12	1.79	9.8	14.4	2.0	0.14	0.100	0	0.11	0.003
Inventive Steel 7	0.082	2.36	11.8	15.3	2.48	0.133	0.100	0.1	-	-
Inventive Steel 8	0.082	0.198	9.7	14.1	2.00	0.140	0.050	0.05	-	-
Inventive Steel 9	0.077	2.05	10.3	13.4	1.98	0.160	0.100	0.1	-	-
Inventive Steel 10	0.21	1.99	10	14.0	2	0.145	0.1	0	0.002	0.003
Inventive Steel 11	0.1	1.23	9.2	14.1	2.03	0.167	0	0	0.2	0.04
Comparative Steel 1	0.086	2.01	4.1	15.9	2.02	0.140	0	0	-	-
Comparative Steel 2	0.085	0.197	4.1	15.8	1.96	0.130	0.100	0.06	-	-
Comparative Steel 3	0.071	2.04	4.0	15.9	0.27	0.210	0.120	0	-	-
Comparative Steel 4	0.087	0.200	6.0	17.9	2.00	0.180	0	0		
Comparative Steel 5	0.019	1.88	10.0	14.1	0.82	0.066	0	0	0.002	0.003

[0038] The hot rolled steel sheet obtained by hot rolling the material prepared as in the above composition at an ordinary rolling temperature was subjected to hot rolling annealing to evaluate the microstructure and phase fraction and the related strength and elongation.

[0039] FIGS. 1 to 4 are photographs showing the hot workability of inventive steels and comparative steels. FIG. 1 shows the inventive steel 8, FIG. 2 shows the inventive steel 9, and FIG. 3 shows the inventive steel 11. Referring to FIGS. 1 to 3, it was confirmed that the inventive steels showed a structure of an austenite single phase or a part of martensite after cooling, so that there was almost no edge crack at the time of hot rolling. In the case of the inventive steel 11 in which some ferrite phases were present at 5% or less, cracks occurred at some edges, but this was not a problem. However, in the case of the comparative steel 4 shown in FIG. 4, a considerable amount of ferrite was present, which caused severe cracking during hot rolling, causing problems in hot rolling.

[0040] On the other hand, the produced material was hot rolled at a normal rolling temperature. The prepared hot rolled steel sheet was subjected to hot rolling annealing to confirm the microstructure and the phase fraction as shown in Table 2 below. After being subjected to hot rolling annealing at 1,100 ° C for about 30 minutes, water cooling was performed, and the structure was observed under an optical microscope. The phase fraction was measured by using a ferrite scope. When the martensite phase was present as an observation result of the optical microscope, the ferrite fraction and the martensite fraction were separated by comparison with the ferrite scope data using an image analyzer.

[Table 2]

	Residual Microstructure	
	Ferrite (%)	Martensite (%)
Inventive Steel 1	-	-
Inventive Steel 2	-	3
Inventive Steel 3	-	-
Inventive Steel 4	-	-
Inventive Steel 5	-	-
Inventive Steel 6	4	-
Inventive Steel 7	-	-

(continued)

	Residual Microstructure	
	Ferrite (%)	Martensite (%)
Inventive Steel 8	-	2
Inventive Steel 9	-	-
Inventive Steel 10	-	-
Inventive Steel 11	4	-
Comparative Steel 1	20	-
Comparative Steel 2	30	-
Comparative Steel 3	37	-
Comparative Steel 4	42	-
Comparative Steel 5	15	62

[0041] Referring to Table 2, it can be seen that, in most of the inventive steels, a matrix phase is an austenite phase and the residual structure is slightly changed depending on the component system, but the ferrite or martensite phase remains. Further, it was confirmed that the residual amount was 5% or less. However, in the case of the comparative steel with severe edge cracking during hot rolling, it was found that most of the steel was a two phase structure composed of the austenite and ferrite phase. Particularly, in the case of the comparative steel 5, most of the microstructure after the hot rolling annealing is transformed into a martensite phase from the austenite, and a part thereof remains in the retained austenite phase. It was confirmed that a considerable amount of an elongated ferrite phase in the rolling direction existed. In the case of the inventive steel at the annealing temperature range, it was confirmed that there was almost no difference in the microstructure except for the difference of crystal grains and the presence of some of the ferrite phase or martensite phase.

[0042] FIGS. 5 to 10 are optical micrographs showing the structures of inventive steels and comparative steels which were heat-treated at a hot rolled annealing temperature of 1,100°C for 30 minutes and then water-cooled.

[0043] FIG. 5 is a photograph showing the microstructure of the inventive steel 2, in which an austenite phase and a residual martensite phase were observed.

[0044] FIG. 6 is a photograph showing the microstructure of the inventive steel 8, in which an austenite phase and a residual ferrite phase were observed.

[0045] FIG. 7 is a photograph showing the microstructure of the inventive steel 9, in which only an austenite phase was observed.

[0046] FIG. 8 is a photograph showing the microstructure of the comparative steel 1, in which a ferrite phase elongated in the rolling direction together with an austenite phase was observed.

[0047] FIG. 9 is a photograph showing the microstructure of the comparative steel 4, in which an austenite phase and a ferrite phase were observed.

[0048] FIG. 10 is a photograph showing the microstructure of the comparative steel 5, in which both a ferrite phase and a martensite phase were observed together with an austenite phase.

[0049] FIGS. 5 to 10 are representative microstructure photographs corresponding to Table 2. It can be confirmed that the measurement results in Table 2 and the observation results in FIGS. 5 to 10 are actually in agreement.

[0050] On the other hand, FIGS. 11 to 14 are photographs showing changes in the microstructure according to the hot rolled annealing temperature of 900 to 1,200 ° C. for a specimen having an alloy composition range of inventive steel 9.

[0051] Even when the hot rolled annealing temperature rises to 900°C or higher, the crystal grains are coarsened, but it has been found that a sufficiently desired structure can be secured.

[0052] FIG. 15 is a graph showing tensile test results of inventive steels and comparative steels according to an embodiment of the present invention.

[0053] Referring to FIG. 15, in the case of the inventive steel, the elongation percentage was more than 40% and the tensile strength was 650 MPa or more. In addition, when the material is deformed or stressed, the values of the stress-strain curve and the tensile strength largely vary according to the deformation behavior of the main phase, austenite phase. In the inventive steels 5 and 8, in which the strain-induced martensite transformation occurs well, the elongation can be secured not less than 40%, and the tensile strength is 1,200 MPa, which indicates that high strength can be secured.

[0054] While the present disclosure has been particularly described with reference to exemplary embodiments, it should be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the present disclosure.

[Industrial Applicability]

[0055] The low alloy steel sheet excellent in strength and ductility according to the embodiments of the present invention is a Cr-Mn austenitic stainless steel in which Ni is omitted, and has excellent physical properties and can be applied to various fields of structural materials such as automotive structural steel sheets.

Claims

1. A low alloy steel sheet excellent in strength and ductility comprising, in percent (%) by weight of the entire composition, 0.05 to 0.3 % of carbon (C), 0.7 to 2.5 % of silicon (Si), 8 to 12 % of manganese (Mn), 13 to 15.5 % of chromium (Cr), 0.5 to 3.0 % of copper (Cu), 0.1 to 0.2 % of nitrogen (N), 0.25 % or less of aluminum (Al), 0.25 % or less of tin (Sn), and the remainder of iron (Fe) and other inevitable impurities,
wherein the microstructure of the low alloy steel sheet comprises at least one of a ferrite phase and a martensite phase at a volume fraction of 5% or less, and the remainder includes an austenite phase.

2. The low alloy steel sheet of claim 1, further comprising 0.2% or less of nickel (Ni).

3. The low alloy steel sheet of claim 1 or 2, further comprising 0.2% or less of molybdenum (Mo).

4. The low alloy steel sheet of claim 1, wherein the elongation of the low alloy steel sheet is 40% or more.

5. The low alloy steel sheet of claim 1, wherein the tensile strength of the low alloy steel sheet is 650 MPa or more.

FIG. 1

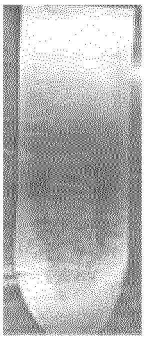


FIG. 2

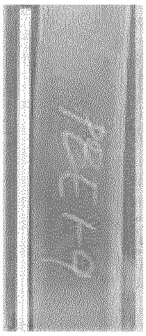


FIG. 3

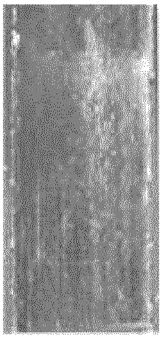


FIG. 4

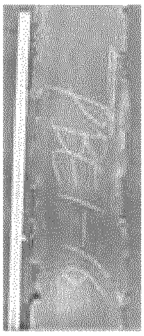


FIG. 5

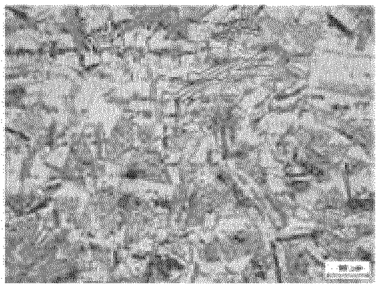


FIG. 6

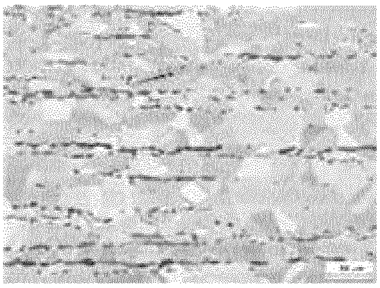


FIG. 7

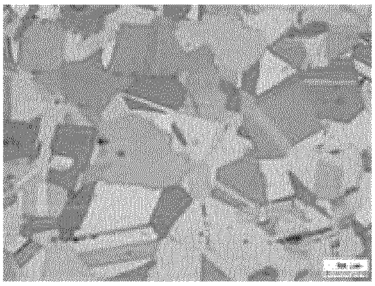


FIG. 8

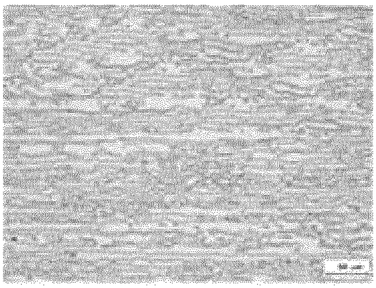


FIG. 9

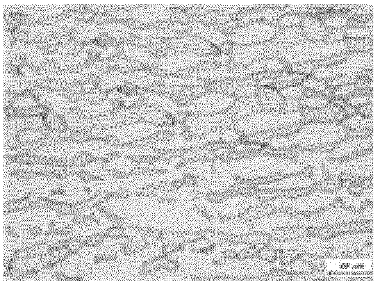


FIG. 10

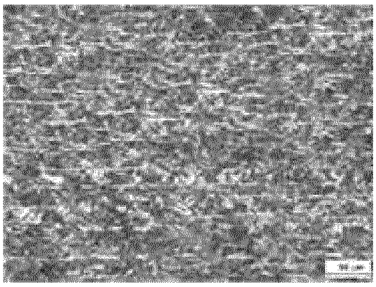


FIG. 11

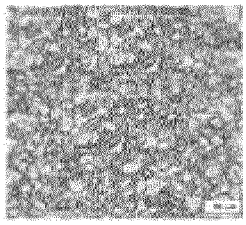


FIG. 12

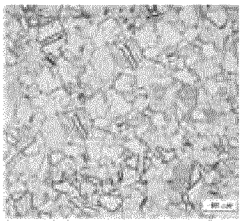


FIG. 13

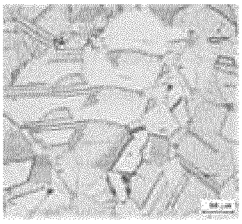


FIG. 14

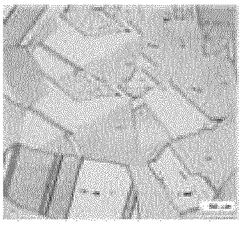
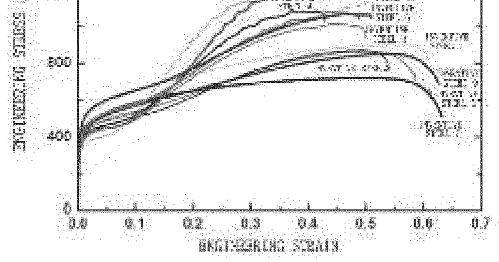


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/005381

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i, C22C 38/34(2006.01)i, C22C 38/02(2006.01)i, C22C 38/20(2006.01)i, C22C 38/58(2006.01)i, C22C 38/60(2006.01)i, C22C 38/22(2006.01)i, C22C 38/42(2006.01)i, C22C 38/44(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 38/38; C21D 9/46; C22C 38/50; C21D 6/00; C21D 8/02; C22C 38/00; C22C 38/58; C22C 38/34; C22C 38/02; C22C 38/20; C22C 38/60; C22C 38/22; C22C 38/42; C22C 38/44

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: chrome, silicon, manganese, copper, carbon, aluminum, tin, ferrite, austenite, martensite, TWIP, TRIP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2014-0105849 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 02 September 2014 See paragraphs [0087]-[0090] and claims 1, 2.	1-5
A	JP 2013-076162 A (JFE STEEL CORP.) 25 April 2013 See paragraph [0081] and claims 1, 6, 7.	1-5
A	US 2008-0006348 A1 (LEVIN, Victor D.) 10 January 2008 See paragraphs [0039]-[0043] and claims 1-3.	1-5
A	US 2015-0329947 A1 (CENTRO SVILUPPO MATERIALI S.P.A.) 19 November 2015 See paragraph [0055] and claim 1.	1-5
A	KR 10-2012-0063793 A (POSCO) 18 June 2012 See claim 1 and figure 1.	1-5

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

* Special categories of cited documents:
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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
10 AUGUST 2017 (10.08.2017)	**10 AUGUST 2017 (10.08.2017)**

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Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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