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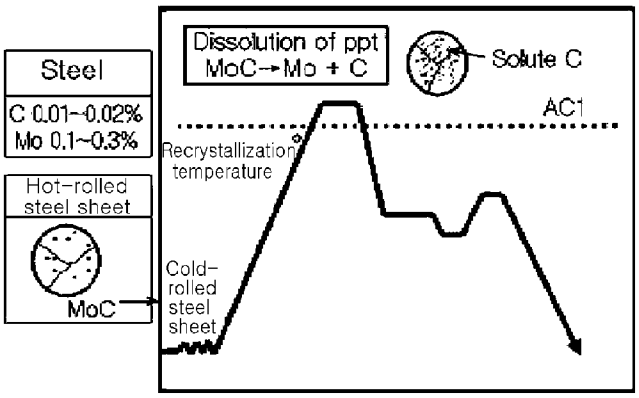
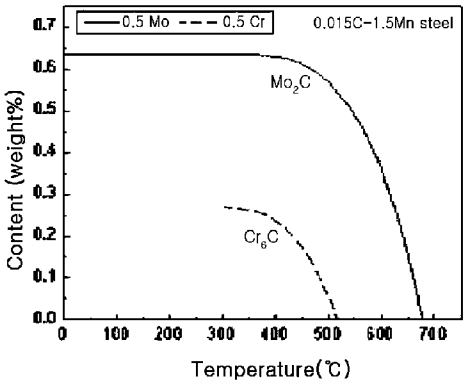
(54) **Title:** DUAL PHASE STEEL HAVING SUPERIOR DEEP DRAWING, AND METHOD FOR MANUFACTURING OF IT





(57) **Abstract:** There are provided a dual phase steel that is used for inner and outer panels of an automobile, can prevent deterioration in development of { 111 } texture and appropriately maintain martensite by Mo and Al in low carbon steel, and a method for manufacturing the same. The dual phase steel includes, by weight: C:0.01 to 0.03%, Si:0.3% or less, Mn: 1.0 to 2.0%, P:0.01 to 0.06%, S:0.015% or less, soluble Al:0.2 to 0.8%, N:0.0030% or less, Mo:0.2 to 1.0%, Cr:0.5% or less, and B:0.0005 to 0.0015%, the balance Fe, and unavoidable impurities. Here, the dual phase steel sheet has a dual phase structure that includes martensite and ferrite. According to an aspect of the present invention, dual phase steel has a tensile strength of 440 to 490 MPa, an elongation of 32%, and an r-value of 1.4 or more.

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Description

DUAL PHASE STEEL HAVING SUPERIOR DEEP DRAWING, AND METHOD FOR MANUFACTURING OF IT

Technical Field

[1] The present invention relates to a dual phase steel sheet that is used for inner and outer panels of an automobile body, and a method for manufacturing the same, and more particularly, to a dual phase steel sheet and a method for manufacturing the same that can prevent deterioration in {111} texture and appropriately maintain the volume fraction of martensite by Mo and Al in low carbon steel.

[2]

[3]

Background Art

[4] In recent years, in order to regulate CO_2 emissions for the conservation of the earth's environment, a need for fuel economy of automobiles has been increased. Further, the safety enhancement based on automobile crashworthiness has also been required to ensure the safety of passengers in car crashes. As such, technologies have been developed in terms of a reduction in weight of an automobile body and reinforcement of the automobile body.

[5] In order to reduce the weight of the automobile body and reinforce the automobile body at the same time, the strength of the material of automotive parts needs to be increased without loss of rigidity of the automotive parts, and the thickness of panels needs to be reduced the automobile body weight. For these reasons, high-strength steel sheets have been widely used for the automotive parts. The more the tensile strength of the steel sheets that are used increases, the more the weight of the automobile body decreases. Therefore, automobile manufactures have made efforts to use high-strength steel sheets for the auto parts. Even dual phase steel having a tensile strength of 490 MPa has been used for outer panels of the automobile body.

[6] Since most of the automotive parts that are made of steel sheets are worked by pressing, excellent press formability has been required. In general, according to a method of improving the press formability, stretching properties and deep drawability need to be improved, but may be different according to the automotive parts. A method of improving the stretching properties by increasing the strength may include a method of allowing a steel sheet to have a composite structure. Dual phase steel has a structure that includes a soft ferrite phase and a hard phase in steel, such that the dual phase steel has a low yield strength and a high work hardening rate. Therefore, the dual phase steel has excellent formability. However, as the strength of the high-strength steel sheet

increases, the high-strength steel sheet has worse deep drawability than a general mild steel sheet. To prevent the deterioration in formability, a technique is required to ensure that an r-value, which is an index of the deep drawability, is equal to or more than a certain value.

[7] In general, according to a method of achieving high-strength steel with a high r-value, carbonitride forming elements, such as Ti and Nb, are added to ultra low carbon steel, and then solid solution strengthening elements, such as Si, Mn, and P, are added thereto. However, when the strength of the ultra-low carbon high-strength steel sheet increases, the yield strength thereof also increases to thereby deteriorate the press formability. Further, plating properties may be deteriorated due to the addition of the elements, such as Mn, P, and Si. Therefore, recently, in order to solve the above-described problems, efforts have been made to maintain advantages of the dual phase steel and ensure an increase in the r-value.

[8] As described above, according to the method of increasing the r-value in the high-strength steel sheet, the carbonitride forming elements, such as Ti and Nb, are added to the ultra-low carbon steel to completely remove solute elements in steel, and then the solid solution strengthening elements, such as Si, Mn, and P, are added thereto.

[9] Japanese Laid-open Publication No. sho 56-139654 discloses a method of obtaining an average r-value of 1.7 by using a non-aging high-strength cold-rolled steel sheet having a tensile strength of 340 to 440 MPa that contains C: 0.002 to 0.015%, Nb: C%x3 to C%x8+0.02%, Si: 1.2% or less, Mn: 0.04~0.8% or less, and P: 0.03 to 0.1% or less. However, as described above, the technique that adds the solid solution strengthening elements to the ultra low carbon steel has problems in that when steel having a tensile strength of 440 MPa or more is manufactured, deterioration in plating properties and secondary work embrittlement as well as poor surface appearance occur due to an increase in the amount of added alloy elements. Further, when high amounts of solid solution strengthening elements are added, the r-value may not increase but rather decrease. In addition, a vacuum degassing process needs to be performed during steelmaking so that the carbon content decreases to the smallest amount of carbon, that is, 0.01%. Therefore, various problems, such as high CO_2 emission during steelmaking and an increase in manufacturing costs may occur.

[10] A high-strength steel sheet that is proposed as an alternative to solve the problems is a dual phase high-strength steel sheet. As described above, however, the dual phase steel has a low r-value due to the hard martensite. Methods of increasing the r-value of the dual phase steel have been proposed since 1980. In Japanese Examined Patent Application Publication No. sho 55-10650, disclosed is a method of cold rolling low carbon steel, batch annealing the cold-rolled low carbon steel at a recrystallization temperature to an AC3 transformation temperature, reheating the batch-annealed steel

at the temperature of 700 to 800°C, and tempering the heated steel so as to manufacture dual phase steel. However, according to this method, manufacturing costs are increased due to the two annealing processes, that is, the continuous annealing is carried out after the batch annealing. Further, according to a technique disclosed in Japanese Laid-open Publication No. sho 55-100934, batch annealing is performed after cold rolling to obtain a high r-value. Here, the batch annealing is performed at intercritical temperature between ferrite and austenite region, and then continuous annealing is performed. According to this technique, Mn is concentrated on austenite from a ferrite phase according to the batch annealing, and then a phase in which Mn is concentrated is changed into an austenite phase according to the continuous annealing. Further, the two phases is obtained in a cooling process. However, according to this method, the batch annealing needs to be performed to concentrate Mn at a relatively high temperature for a long period of time. Further, a large number of processes are performed to reduce economic efficiency. In addition, problems, such as close contact between steel sheets, generation of temper colors, and a reduction in life of covers in a furnace body, may occur.

[11] In recent years, a technique of increasing an r-value in dual phase steel has been disclosed in Japanese Examined Patent Application Publication No. hei 1-35900 that appropriately controls the carbon content and the V content to increase the r-value. That is, before recrystallization annealing, carbon in steel is precipitated as V-based carbides so as to reduce the amount of solute carbon as much as possible. In this way, the high r-value can be obtained. Then, the steel is heated in the dual phase region of ferrite and austenite to dissolve the V-based carbides again, which increases the carbon content in austenite. Then, a martensite phase is formed according to a cooling process. However, since V is very expensive, a significant increase in manufacturing costs is caused. Further, VC that is generated in the hot-rolled steel sheet may increase deformation resistance during cold rolling, which causes troubles in facilities. In addition, in Japanese Laid-open Publication No. 2003-64444, a high-strength steel sheet that contains a certain amount of carbon and has an average r-value of 1.3 or more is manufactured. The high-strength steel sheet further contains at least one kind of bainite, martensite, and austenite by 3% or more. According to the manufacturing method, the texture is developed by carrying out cold rolling at a reduction ratio of 30 to 95% and then forming precipitates or clusters of Al and N. However, according to the method, since annealing is performed to obtain an appropriate r-value and heating is performed to form the texture after cold rolling, deterioration in productivity is caused. Further, since the obtained texture has a relatively high second phase fraction, it is difficult to reliably ensure good balance between strength and ductility.

Disclosure of Invention

Technical Problem

[12] An aspect of the present invention provides dual phase steel of martensite and ferrite that can maintain high strength and obtain a high r-value.

[13]

Technical Solution

[14] According to an aspect of the present invention, there is provided a dual phase steel sheet having excellent deep drawability, including by weight%: C:0.01 to 0.03%, Si:0.3% or less, Mn:1.0 to 2.0%, P:0.01 to 0.06%, S:0.015% or less, soluble Al:0.2 to 0.8%, N:0.0030% or less, Mo:0.2 to 1.0%, Cr:0.5% or less, and B:0.0005 to 0.0015%, the balance Fe, and unavoidable impurities. Here, wherein the dual phase steel sheet has a dual phase structure that includes martensite and ferrite.

[15] In the dual phase steel sheet that can prevent deterioration of {111} texture and appropriately maintain the martensite, a volume fraction of the martensite and/or a size of the martensite may be appropriately controlled to obtain a desired r-value. The martensite may have a size of 2.2 □ or more and a fraction of 2 to 5%.

[16] Precipitation and re-dissolution of Mo carbides that occur during annealing may affect the {111} texture and the fraction of the martensite, and the Mo carbides may be present in the steel sheet after annealing.

[17] Various kinds of steel sheets may be used as the dual phase steel sheet, and the dual phase steel sheet may be selected between a cold-rolled steel sheet and a plated steel sheet that has a hot dip galvanized layer formed at one or more surfaces thereof.

[18] The dual phase steel sheet may have a tensile strength of 440 to 490 MPa, an elongation of 32% or more, and an r-value of 1.4 or more.

[19] According to another aspect of the present invention, there is provided a method for manufacturing a dual phase cold-rolled steel sheet having excellent deep drawability, the method including: homogenizing steel slabs containing, by weight%, C:0.01 to 0.03%, Si:0.3% or less, Mn:1.0 to 2.0%, P:0.01 to 0.06%, S:0.015% or less, soluble Al:0.2 to 0.8%, N:0.0030% or less, Mo:0.2 to 1.0%, Cr:0.5% or less, B:0.0005 to 0.0015, the balance Fe, and unavoidable impurities, at a temperature of 1200℃ or more, hot rolling the homogenized slabs at a finish rolling temperature of 900 to 950℃, and coiling the hot-rolled slabs at a temperature of 700 to 750℃ to obtain a hot-rolled steel sheet; cold rolling the hot-rolled steel sheet at a reduction of 70 to 80%; continuously annealing the cold-rolled steel sheet at a temperature of 800 to 850℃; and temper rolling the continuously annealed steel sheet at a reduction ratio of 1.0%. Mo carbides may be included in the hot-rolled steel sheet.

[20]

[21]

Advantageous Effects

[22] An aspect of the present invention is to provide a dual phase steel sheet having high strength for drawing that has a low yield ratio and high elongation, which are typical characteristics of dual phase steel, can reduce the weight of automobiles by improving deep drawability, and can be used as inner and outer panels of the automobile body, and a method for manufacturing the same.

Brief Description of the Drawings

[23] FIG. 1 a graph illustrating how Mo affects the material of steel that contains carbon of 0.015%.

[24] FIG. 2 is a graph illustrating how Mo affects the material of steel that contains carbon of 0.03%.

[25] FIG. 3 is a schematic view illustrating a mechanism

[26] by which addition of Mo increase an r-value.

[27] FIG. 4 is a graph illustrating how a transformation fraction of a second phase affects the r-value.

[28] FIG. 5 is a graph illustrating how the size of a transformation structure of the second phase affects the r-value.

[29] FIG. 6 is a photographic diagram illustrating microstructures of a cold-rolled steel sheet and an annealed steel sheet according to addition of Al.

[30] FIG. 7 is a diagram illustrating microstructures of a hot-rolled steel sheet and an annealed steel sheet according to a hot-rolling coiling temperature that affects the r-value.

[31]

Best Mode for Carrying Out the Invention

[32] Hereinafter, exemplary embodiments of the present invention will be described in detail.

[33] In general, in order to increase an r-value of a cold-rolled steel sheet, a method of reducing the amount of solute carbon or nitrogen that remains before recrystallization annealing after cold rolling or a method of making a structure of a hot-rolled steel sheet a microstructure to develop {111} recrystallization texture has been used. However, since a certain amount of solute carbon needs to be contained in a dual phase steel sheet to form martensite, the contained carbon results in deterioration in the {111} texture during annealing. Therefore, a low r-value is obtained.

[34] The present inventors have devised the present invention on the basis of the fact that the r-value of the dual phase steel can be increased by appropriately maintaining the amount of martensite while preventing deterioration in the {111} recrystallization

texture of ferrite that forms a mother phase. That is, according to an exemplary embodiment of the present invention, the Mn content and the Mo content are appropriately controlled while the carbon content is in a range between 0.01 to 0.03 by weight % (hereinafter, simply referred to as %), which is slightly lower than that of a dual phase steel sheet according to the related art, such that a certain amount of martensite is ensured, and at the same time, the deterioration in the {111} recrystallization texture is prevented.

[35] FIGS. 1 and 2 are graphs illustrating values of tensile strength, elongation, and an r-value that change according to the Mn content and Mo content in steel having a carbon content of 0.015% and steel having a carbon content of 0.03% that change at the same time. As shown in FIGS. 1 and 2, as the Mo content increases, the tensile strength and the r-value of each of the steel having the carbon content of 0.015% and the steel having the carbon content of 0.03% gradually increase, and the elongation value thereof gradually decreases. Further, as the Mn content increases, the tensile strength increases but the elongation value and the r-value gradually decrease. According to the results, Mo increases the r-value as well as the strength.

[36] The present inventors have performed various kinds of experiments to find out how Mo affects the r-value, and reached a conclusion as follows. That is, in order to examine the effect of Mo, the present inventors observed precipitates that are formed during operations of heat treatment, that is, rasing temperature-crack-slow cooling-rapid quenching, which are performed during continuous annealing after cold rolling. As a result of the observation, it can be found that Mo-based carbides that exist in the hot-rolled steel sheet are re-dissolved during the heating process of the heat treatment. According to the experiments, it can be found that the temperature at which the Mo-based carbides are re-dissolved is similar with an arbitrary temperature at which re-crystallization of ferrite is performed. This means that the Mo-based carbides fix the solute carbon at an early stage of the recrystallization of the ferrite so as to prevent deterioration in recrystallization texture that occurs due to the carbon to some extent. That is, the Mo-based precipitates that exist in the hot-rolled steel sheet are present at an early stage of annealing recrystallization when the {111} texture is formed, and fixes a part of the solute carbon in steel to thereby develop the {111} texture. Then, the Mo-based precipitates are re-dissolved at a high temperature to provide a sufficient amount of solute carbon to form martensite. Therefore, dual phase steel is obtained in the final process.

[37] FIG. 3 is a view illustrating a mechanism by which Mo in the inventive steel affects an increase in the r-value, and the thermodynamic behavior of Mo-based carbides, which illustrates the above-described phenomenon. As a result of a thermodynamic analysis of the Mo-based precipitates in order to check the behavior of the Mo-based

carbides that is shown in the experiments, as shown in FIG. 3, the precipitation temperature of the Mo-based carbides is around 680℃, which is equal to or more than initial temperature at which the recrystallization texture is developed. Therefore, it is possible to increase the r-value. Even though Cr is a carbide forming element that is similar to Mo, as shown in FIG. 3, the precipitation temperature of Cr is very low, that is, 500℃ or less, and thus Cr is dissolved before the recrystallization texture is developed. It cannot be expected that Cr affects the {111} texture. According to a result of the experiments conducted by the present inventors, it can be found that the addition of Cr hardly affects the increase in the r-value despite the fact that the Cr content may cause a slight difference. However, as shown in FIGS. 1 and 2, a change in the r-value according to the increase in the amount of Mo is connected to Mn. In general, Mn is known as a hardenability improving element in steel having a trans-formation microstructure. As the Mn content increases, the amount of martensite increases. Even though the r-value of the dual phase steel increases by adding Mo to the inventive steel, if the Mn content excessively increases, the amount of martensite in steel increases to reduce the r-value. Therefore, it is very important to appropriately control the Mn content and control the distribution of martensite that has a trans-formation microstructure. In consideration of these facts, according to the exemplary embodiment of the present invention, the content Mn and the content Mo are controlled.

[38] FIGS. 4 and 5 are views illustrating how the distribution of martensite affects the r-value of the dual phase steel. That is, in FIGS. 4 and 5, the present inventors changed various kinds of components and operating conditions, and made a comparison between generated martensite and the r-value by fraction and size functions. According to the two results, as a fraction of the martensite increases and the size of martensite decreases, the r-value gradually decreases. Therefore, preferably, the fraction and size of the martensite are appropriately determined on the basis of strength properties together with the r-value. According to the above-described results, when the target r-value is 1.4 or more, it is most preferable that the fraction of the martensite be in the range of 2 to 5% and the martensite is 2.2 □ or more.

[39] Referring to FIGS. 1 and 2, it may be possible to increase the r-value in the dual phase steel by appropriately controlling the Mo content and the Mn content. Further, referring to FIG. 4, if the fraction and size of martensite are controlled, it is possible to more reliably obtain a high r-value. Further, in order to more reliably obtain the high r-value, the present inventors took into account the addition of other elements in addition to the control of the Mo content and the Mn content. As a result of reviewing material characteristics by using various kinds of elements, the present inventors have found out that Al significantly increases the r-value. Particularly, Al controls the fraction of the

martensite so that the martensite fraction is in the range of, for example, 2 to 5%, and remarkably increases the size of martensite. FIG. 6 is a photographic diagram showing a result of observation on a behavior of Al in terms of microstructures. That is, when the Al content of 0.04% is added, very coarse pearlite is present in the hot-rolled steel sheet. However, when the Al content increases to 0.4%, which is in the range according to the inventive steel, the amount of pearlite in the hot-rolled steel sheet significantly decreases. In general, Al increases mobility of the carbon. Therefore, when the Al content increases to 0.2% or more according to the exemplary embodiment of the present invention, the effect of dispersing pearlite in the hot-rolled steel sheet is obtained because of the increase in mobility of the carbon. The effect of dispersing the pearlite prevents deterioration in the recrystallization texture during annealing after cold rolling the dual phase steel. Meanwhile, as shown in FIG. 6, the addition of Al does not inhibit growth of annealed recrystallized grains because of the dispersion effect of carbon, and thus the annealed ferrite grains are coarsened. Therefore, the martensite grains are coarsened because of a reduction in area of the grains. That is, the addition of Al causes the coarsening of the martensite grains as well as the coarsening of the ferrite because of the effect of dispersing the pearlite during hot rolling, such that the r-value is significantly increased. According to the research conducted by the present inventors, when Al of 0.2% or more is added, the r-value increases to 0.1 to 0.2. However, when the Al content of 0.8% or more is added, the r-value does not increase any more. Further, the excessive addition of Al results in problems, such as an increase in oxides when steelmaking and a decrease in the alloying degree when manufacturing a hot-plated steel sheet.

[40] Another factor that is considered to prevent a decrease in the r-value in the inventive steel is a coiling temperature during hot rolling. That is, according to the research conducted by the present inventors, it can be found that the microstructure of the hot-rolled steel sheet greatly affects the r-value after annealing. That is, in general, in the case of the dual phase steel, the hot-rolled steel sheet has a dual phase structure that includes ferrite and pearlite, transformed ferrite, or a structure that includes transformed ferrite and pearlite. However, according to the research by the present inventors, when the hot-rolled steel sheet has the structure including ferrite and pearlite, the r-value decreases due to the remains of the pearlite during annealing. However, as described above, this problem can be solved by the addition of Al. However, even when the texture of the hot-rolled steel sheet only includes the transformed ferrite without pearlite, the r-value decreases during annealing. According to the research result obtained by the present inventors, uneven segregation of the carbon present in the transformation structure, and transformation stress field that is generated by the carbon segregation adversely affect the development of the {111}

texture during annealing recrystallization. Therefore, in order to obtain the r-value, which is equal to or more than a certain value, in the dual phase steel that is required in the exemplary embodiment of the present invention, it is very important to prevent the generation of the transformed ferrite in the hot-rolled steel sheet. A method of preventing the generation of the transformed ferrite is a method of controlling the coiling temperature during hot coiling. FIG. 7 is a photographic diagram illustrating a change in the hot-rolled structure according to a change in the hot-rolling coiling temperature in Mo-containing steel. As shown in FIG. 7, it can be seen that transformed ferrite generated at a low temperature of 650℃ disappears at a coiling temperature of 700℃, and at a coiling temperature of 750℃, a ferrite structure that has different sizes of gains is obtained. The r-value is very low, that is, approximately 1.0 during low-temperature coiling. However, as the coiling temperature increases, the r-value increases. The R-value at the coiling temperature of 750℃ is almost similar to that at the coiling temperature of 700℃. According to the above-described results, it can be found that there is a certain range of coiling temperature in the dual phase steel to increase the r-value. In the case of the inventive steel, the coiling temperature is in the range of 700 to 750℃.

[41] Hereinafter, a description of the inventive steel will be described in detail.

[42] Preferably, the carbon (C) content is in the range of 0.01 to 0.03%.

[43] C is one of the most important elements in the inventive steel. C contributes to high strength and promotes generation of martensite in dual phase steel. When the C content increases, the amount of martensite in steel increases. Therefore, in order to obtain the r-value while an appropriate amount of martensite is contained as required in the inventive steel, the C content needs to be appropriately controlled. When the C content is less than 0.01%, it is difficult to form a martensite phase that forms dual phase steel. However, in order to reliably ensure a predetermined amount of martensite, it is preferable that the C content is 0.015% or more. However, when the C content exceeds 0.03%, an excessive amount of martensite is formed in steel, and thus it is easy to manufacture the dual phase steel. However, the manufactured dual phase steel has a tensile strength exceeding 440 to 490 MPa that is required in the inventive steel. Further, the drawability is deteriorated due to the excessive amount of solute carbon and martensite in steel.

[44] Preferably, the silicon (Si) content is 0.3% or less.

[45] Si promotes ferrite transformation and increases the C content in untransformed austenite, such that it becomes easy to form a composite structure including ferrite and martensite, and the solid-solution strengthening effect of Si is caused. However, when the Si content increases, paintability of galvanized steel is deteriorated to result in poor wettability and poor coating quality. Therefore, when a galvanized steel sheet is man-

ufactured, the Si content is preferably as low as possible. When the coating properties are not considered or a method of preventing deterioration in the coating properties by the addition of Si is selected, the Si content is not necessarily 0.3% or less. When the amount of element that causes deterioration in coating properties is controlled as small as possible, it is preferable that the Si content be limited to 0.3% or less.

[46] Preferably, the Manganese (Mn) content is in the range of 1.0 to 2.0%.

[47] Mn is used to produce grain refinement without loss of ductility, and completely precipitates sulfur in steel as MnS to prevent hot brittleness from occurring due to generation of FeS. Further, Mn is an element that strengthens steel. At the same time, Mn reduces a critical cooling rate at which a martensite phase is obtained in dual phase steel, such that Mn facilitates the generation of martensite. In order to obtain these results, preferably, the Mn content is 1.0% or more. However, when the Mn content exceeds 2%, strength rapidly increases and formability is deteriorated. Particularly, when a hot-plated steel sheet is manufactured, a large amount of oxides, such as MnO, are formed on the surface during annealing, which results in deterioration in plating adhesion. Further, product quality may be reduced due to coating defects, such as a stripe.

[48] Preferably, the phosphorus (P) content is in the range of 0.01 to 0.06%.

[49] P is a substitutional alloy element that has the highest solid solution strengthening effect, improves planar anisotropy, and increases strength. To do so, preferably, P is 0.01% or more. However, when the P content exceeds 0.06%, the strength increases, and P is segregated along grain boundaries, which results in secondary work embrittlement and deterioration in weldability. Further, in the case of the galvanized steel sheet, P prevents Fe dispersion into a coating layer from the steel sheet at the grain boundaries during alloying after hot plating, which causes a reduction in the alloying degree. Therefore, it is preferable that the P content be in the range of 0.01 to 0.06%.

[50] Preferably, the sulfur (S) content is 0.015% or less.

[51] S is an element that needs to be precipitated as a sulfide MnS at a high temperature so as to prevent hot shortness that is caused by FeS. However, when the S content is excessive, S that remains after being precipitated as MnS embrittles the ground boundaries to cause hot brittleness. Further, even though S contained in steel is completely precipitated to form MnS precipitates, if the S content is high, material degradation occurs due to the excessive precipitates. Therefore, it is preferable that the S content be 0.015% or less.

[52] Preferably, the aluminum (Al) content is in the range of 0.2 to 0.8%.

[53] In general, Al is added to deoxidize steel. Al fixes solute nitrogen in steel as AlN to prevent deterioration in anti-aging properties. Further, Al is a ferrite forming element t hat controls a fraction of a dual phase of ferrite and austenite during annealing.

However, in the inventive steel, Al disperses pearlite during hot rolling to reduce the deterioration in the recrystallization {111} texture that occurs due to the inhomogeneous distributions of carbon during annealing. Further, the addition of Al coarsens grains during annealing and increases the size of martensite at the same fraction, thereby increasing the r-value. In order to achieve the above results, it is preferable that the Al content of 0.2% or more be added. However, when Al exceeds 0.8%, a microstructure is obtained to cause deterioration in formability. Further, the addition of the excessive Al results in an increase in oxide inclusions deteriorating the surface quality. In addition, the addition of the excessive Al causes an increase in manufacturing costs. Therefore, it is preferable that the Al content be in the range of 0.2 to 0.8%.

[54] Preferably, the nitrogen (N) content is 0.003% or less.

[55] N is in a solid solution state before or after annealing so that the formability of the steel is deteriorated. Further, N causes more aging degradation than any other interstitial elements, N needs to be fixed by Ti or Al. In general, nitrogen diffuses at a higher rate than carbon. Therefore, when N exists in the form of solute N, it causes serious degradation in aging resistance as compared with the solute C. Further, the remaining solute N increases yield strength, and decreases the elongation and the r-value. Therefore, it is preferable that the N content be 0.0030% or less according to the exemplary embodiment of the present invention.

[56] Preferably, the molybdenum (Mo) content is in the range of 0.2 to 1.0%.

[57] Mo is one of the most important elements that are considered in the inventive steel. Mo is in solid-solution state in steel to increase the strength or form Mo-based carbides. Further, like Mn or the like, Mo decreases a critical cooling rate at which a martensite phase is obtained, such that it is possible to easily obtain the martensite phase during cooling after annealing. In the inventive steel, Mo is used to manufacture dual phase steel and form Mo-based carbides. That is, Mo is used to form Mo-based carbides with the added carbon during hot rolling so as to reduce the amount of solute C in steel, and the formed Mo-based carbides are re-dissolved during annealing after the formation and the development of the {111} texture according to recrystallization during annealing so as to improve hardenability. In this way, the dual phase steel and the drawability may be obtained at the same time. To do so, it is preferable that the Mo content be 0.2% or more. When the Mo content exceeds 1.0%, the amount of Mo-based carbides increases. The addition of the excessive Mo increases hardenability and forms a large amount of martensite in steel. As a result, Mo results in an increase in hardenability rather than an increase in r-value, which causes material degradation. Further, since Mo is a very expensive element, the amount of Mo needs to be as small as possible so as to prevent a sharp increase in manufacturing costs. Therefore, in the

inventive steel, the Mo content is in the range of 0.2 to 1.0%.

[58] The chromium (Cr) content is 0.5% or less.

[59] Like Mo, Cr is an element that improves hardenability and forms carbides so that Cr has the operation and effect similar to Mo. However, since Cr-based carbides are dissolved at a very low temperature, even when Cr is used to form the Cr-based carbides during hot rolling to reduce the solute C in steel, the formed Cr-based carbides are dissolved before recrystallization during annealing. Therefore, Cr does not make significant contribution to the development of {111} texture. However, Cr plays an important role in generating martensite. Particularly, since Cr is cheaper than Mo, it is preferable that a predetermined amount of Cr be used to manufacture dual phase steel. In the inventive steel, the Cr content is 0.5% or less. When the Cr content exceeds 0.5%, since the amount of martensite in steel increases significantly, strength is increased and material degradation is caused.

[60] Preferably, the boron (B) content is in the range of 0.0005 to 0.0015%.

[61] B is present in steel as an interstitial element. B is in solid-solution state along grain boundaries or bonded to nitrogen to form boron nitrides BN. B as well as Mn plays an effective role in forming martensite. Since B has a greater effect on the material for the content of B, the B content needs to be strictly limited. That is, when the amount of B that is added to steel is equal to or more than a predetermined value, a transformation structure starts to be developed during hot rolling, which causes a decrease in the r-value after annealing. In the inventive steel, in consideration of these characteristics and the current capability for steelmaking with respect to the addition of B, the B content is in the range of 0.0005 to 0.0015%.

[62] Alloying elements may be added according to the steel having the above-described composition if necessary. However, the content of the alloying components, such as carbide forming elements Ti and Nb, which may affect the above-described operation of Mo, needs to be controlled. The addition of the alloying elements can be considered when they do not adversely affect the operation of Mo.

[63] Steel according to the exemplary embodiment of the present invention is dual phase steel that includes a dual phase of martensite and ferrite. Therefore, the strength and the r-value are affected according to the fraction of martensite and ferrite. That is, as described above with reference to FIGS. 4 and 5, as the fraction of the martensite decreases and the size of martensite increases, the r-value gradually increases. Therefore, the fraction and size of the martensite are determined in consideration of the r-value, it is possible to select appropriate values in FIGS. 4 and 5. The fraction of the martensite is in the range of 1 to 11%, and preferably, 2 to 8%, and more preferably, 2 to 5%. The martensite is 1 □ or more, and preferably, 2.2 □ or more.

[64] As long as a steel sheet has the above-described components according to the

exemplary embodiment of the present invention, and a fraction and size of martensite that are determined on the basis of high strength and a high r-value, kinds of steel sheets are not limited. Examples of the steel sheets may include hot-rolled steel sheets, cold-rolled steel sheets, and coated steel sheets. If necessary, a steel pipe may be used. According to an exemplary embodiment of the present invention, the coated steel sheet is used. Preferably, a coating layer is a zinc galvanized layer.

[65] According to an exemplary embodiment of the present invention, Mo is used to increase the strength and form Mo-based carbides so as to ensure a low yield ratio and a high work-hardening rate, and Al of 0.2% or more is added to obtain the effect of dispersing pearlite during hot rolling and coarsen grains produced by annealing to thereby ensure high elongation and an average r-value of 1.4 or more, such that dual phase high-strength cold-rolled steel having a tensile strength of 440 to 490 MPa is proposed.

[66] Hereinafter, a method for manufacturing the above-described steel according to an exemplary embodiment of the present invention will be described. This manufacturing method relates to a method for manufacturing a cold-rolled steel sheet and a hot-dip galvanized steel sheet. According to the manufacturing method, hot rolling is performed at a relatively high coiling temperature in a range of 700 to 730℃, such that grains during hot rolling are controlled to have a ferrite single-phase structure, not a transformation microstructure. Further, according to the manufacturing method, Al is added to promote the pearlite dispersion effect, and Mo is used to facilitate the development of the recrystallization {111} texture during heating for annealing.

[67] On the basis of the above-described composition, steel slabs are heated at a temperature of 1200℃ so that an austenite before hot rolling can be sufficiently homogenized. The hot rolling finishes at a temperature range of 900 to 950℃, which is just above Ar_3 temperature.

[68] When the slab reheating temperature is 1200℃ or less, steel has a structure in which austenite grains do not have the same size but a duplex grain size exits, which results in material degradation. Further, when a hot-rolling finish temperature is less than 900℃, the top, tail, and edge of the hot-rolled coil become ferrite-phase regions, which increases planar anisotropy and deteriorates formability. Further, when the temperature exceeds 950℃, significantly coarse particles are formed, and thus defects, such as orange peel, are likely to occur on the surface after processing.

[69] As described above, after hot rolling is carried out, hot coiling is performed at a temperature range of 700 to 750℃, which is one of the most essential characteristics of the exemplary embodiment of the present invention. In a case of the inventive steel that contains more elements, such as Mo, which improve hardenability, if the coiling temperature is less than 700℃, a transformation structure is formed in the hot-rolled

steel sheet to prevent the development of the {111} recrystallization texture during annealing. When the coiling temperature exceeds 750°C, growth of the ferrite grains is activated to coarsen the grains and cause non-homogenized grains, which results in material degradation. Therefore, in order to solve the above-described problems, in the inventive steel, the coiling temperature is limited to the range of 700 to 750°C.

[70] The steel after hot rolling is pickled according to a general method, and then subjected to cold rolling at a reduction ratio of 70 to 80%. In the inventive steel, in order to maximize the development of the recrystallization texture during annealing, it is preferable that the cold rolling be performed at a reduction ratio of 70% or more. However, when the steel is subjected to the cold rolling at a reduction ratio exceeding 80%, significant grain refinement occurs due to too high reduction ratio, which results in material degradation. Further, the r-value gradually decreases due to the significant increase in the reduction ratio during cold rolling.

[71] The steel after cold rolling is subjected to continuous annealing at a temperature range of 800 to 800°C according to a general method. Here, preferably, the annealing temperature is in the range of 800 to 850°C, so that the high elongation and the increase in the r-value, which are required in the inventive steel, can be obtained. That is, when the annealing temperature is 800°C or less, it is slightly low in maximizing the development of the {111} recrystallization texture. When the annealing temperature exceeds 850°C, the formability can be improved, but deep drawability and strength are deteriorated due to the excessive annealing.

[72] Dual phase steel that is manufactured according to the above-described manufacturing method is subjected to temper rolling at the small reduction ratio to control the shape. Here, according to the exemplary embodiment of the present invention, the reduction ratio is preferably 1.0% or less. When the temper rolling is performed at the reduction ratio exceeding 1.0%, the yield strength increases and the elongation decreases. In addition, when a coated steel sheet is manufactured as the inventive steel, the excessive temper rolling results in deterioration in coating adhesion, and thus the coating layer is peeled off. In order to solve these problems, it is preferable that the temper rolling be performed at the reduction ratio of 1.0% or less.

[73] A hot-plated steel sheet may be manufactured as the inventive steel. The coated steel sheet is manufactured according to the same conditions as those of the cold-rolled steel sheet. Here, the conditions may include annealing temperature and a reduction ratio during temper rolling.

Mode for the Invention

[74] Hereinafter, exemplary embodiments of the present invention will be described in detail.

[75] [Example]

[76] Table 1 as shown below illustrates chemical components of inventive steels, in which the amount of C, Mn, Sol.Al, Mo, and Cr is strictly controlled, and chemical components of comparative steels. Steels according to 1 to 10 are inventive steels, and steels according to 11 to 16 are comparative steels.

[77] Table 2 illustrates processing results and material results of steel materials that are produced by using the steels shown in Table 1. The steels are subjected to hot rolling, cold rolling at a reduction ratio of approximately 75%, continuous annealing at a temperature of 830℃, galvanizing at a galvanizing temperature of 460℃, and temper rolling at a reduction ratio of 0.8%. Then, tensile strength, elongation, and an average r-value are measured. Further, from the observation of microstructures, results of calculating a fraction of martensite, which has a transformation structure, and an average size of a martensite phase are shown in Table 2. The coiling temperature CT varies according to the steel materials. The cold coiling is performed at a temperature of 540 to 620℃, and the hot coiling is performed at a temperature of 700 to 730℃.

[78] Table 1

steel kind	Chemical component (wt %)										Remark
	C	Si	Mn	P	S	Sol.Al	Mo	Cr	N	B	
1	0.015	0.049	1.63	0.011	0.0030	0.40	0.30	0.10	0.0022	0.0005	Inventive Steel
2	0.015	0.051	1.61	0.011	0.0028	0.38	0.25	0.10	0.0017	0.0005	Inventive Steel
3	0.015	0.052	1.63	0.020	0.0029	0.29	0.35	0.12	0.0020	0.0007	Inventive Steel
4	0.015	0.051	1.63	0.020	0.0030	0.49	0.25	0.21	0.0015	0.0006	Inventive Steel
5	0.022	0.053	1.72	0.012	0.0035	0.42	0.30	0.09	0.0013	0.0007	Inventive Steel
6	0.021	0.053	1.69	0.025	0.0036	0.51	0.41	0.22	0.0021	0.0008	Inventive Steel
7	0.025	0.062	1.73	0.030	0.0021	0.39	0.54	0.20	0.0027	0.0003	Inventive Steel
8	0.021	0.051	1.41	0.040	0.0041	0.44	0.58	0.15	0.0021	0.0005	Inventive Steel

9	0.027	0.043	1.53	0.020	0.0031	0.40	0.62	0.21	0.0019	0.0005	Inventive Steel
10	0.020	0.044	1.61	0.050	0.0029	0.50	0.60	0.35	0.0027	0.0006	Inventive Steel
11	0.051	0.052	1.71	0.015	0.0031	0.29	0.21	0.12	0.0026	0.0007	Comp. Steel
12	0.0052	0.041	1.63	0.021	0.0024	0.31	0.35	0.21	0.0025	0.0005	Comp. Steel
13	0.019	0.051	1.92	0.023	0.0035	0.42	0.05	0.61	0.0019	0.0008	Comp. Steel
14	0.016	0.048	2.01	0.024	0.0021	0.04	0.24	0.10	0.0027	0.0006	Comp. Steel
15	0.024	0.031	1.24	0.014	0.0041	0.07	0.02	0.31	0.0021	0.0003	Comp. Steel
16	0.041	0.027	1.41	0.021	0.0027	0.31	0.07	0.21	0.0018	0.0007	Comp. Steel

[79]

[80] Table 2

Steel kind	CT	TS(MPa)	El (%)	r-bar.	Second phase fraction (%)	Second phase size(□)	Remark
1	720℃	448.2	36.9	1.57	3.5	2.6	Inventive Steel
	550℃	479.3	32.1	1.08	3.1	1.7	Comp. Steel
2	700℃	447.7	40.0	1.59	3.2	3.1	Inventive Steel
	620℃	462.3	35.7	1.10	2.9	1.5	Comp. Steel
3	750℃	451.8	36.4	1.54	3.8	2.5	Inventive Steel
	540℃	481.2	31.0	1.01	3.7	1.0	Comp. Steel
4	710℃	451.3	36.8	1.50	3.1	3.4	Inventive Steel
5	700℃	502.9	32.3	1.44	4.2	2.5	Inventive Steel
6	700℃	503.3	32.7	1.41	4.3	2.6	Inventive Steel
7	720℃	512.7	33.4	1.46	4.4	2.8	Inventive Steel
8	730℃	497.3	34.5	1.52	3.9	3.0	Inventive Steel

9	700℃	521.4	32.2	1.43	4.7	2.9	Inventive Steel
10	700℃	499.6	34.7	1.49	4.2	2.9	Inventive Steel
11	720℃	541.2	26.1	1.02	7.2	1.3	Comp. Steel
12	730℃	451.3	27.2	1.41	0	0	Comp. Steel
13	700℃	462.3	37.4	1.21	2.7	2.1	Comp. Steel
14	700℃	452.1	35.4	1.31	3.2	1.8	Comp. Steel
15	700℃	502.1	33.2	1.03	3.7	1.6	Comp. Steel
16	700℃	512.3	34.1	1.02	6.7	1.1	Comp. Steel
Second phase refers to martensite.							

[81]

[82] Steel kinds 1 to 10 have a tensile strength of 447.7 to 521.4 MPa, an elongation of 32.2 to 40.0%, and an average r-value of 1.41 to 1.59. Each of the steel kinds 1 to 10 satisfies the conditions of the inventive steel, that is, tensile strength of 440 to 490 MPa, an elongation of 32% or more, and an average r-value of 1.4 or more. Further, each of the steel kinds 1 to 10 has a high r-value by appropriate addition of Mo and Al, martensite, which forms a second phase and has a fraction of 3.2 to 4.7%, a martensite phase having an average size of 2.5 to 3.4 □. Each of the steel kinds 1 to 10 satisfies conditions of a second phase having a fraction of 2 to 5% and an average size of 2.2 □ or more.

[83] Meanwhile, when the steel kinds 1 to 3 are coiled at a temperature range of 540 to 620℃, the cold coiling causes formation of a transformation structure and a decrease in size of grains, such that the strength increases and the elongation decreases. Particularly, low temperature transformation phases that are generated during hot rolling cause a decrease in the average r-value, that is, an average r-value of approximately 1.0 is obtained.

[84] Further, the comparative steel (11) has components that satisfy the conditions according to the exemplary embodiment of the present invention. However, the comparative steel (11) has the C content of 0.051%, which is higher than that of the exemplary embodiment of the present invention, that is, the C content of 0.015 to 0.030%. The C content is so high that martensite in steel has a microstructure and a high fraction of 7.2%. Therefore, the comparative steel (11) has the increased strength and does not satisfy the elongation of 32% or more, which is required in the exemplary embodiment of the present invention.

[85] Contrary to the steel kind 11, the steel kind 12 is steel that has a C content of 0.0052%, which is much lower than that of the exemplary embodiment of the present

invention. Since the absolute quantity of the added carbon decreases, dual phase steel is not obtained but a single phase of ferrite is only obtained. Further, since the material of the steel kind 12 corresponds to material results of steel having a ferrite single-phase structure, it is different from the material of the dual phase steel.

[86] The comparative steel (13) has the Mo content of 0.05% and the Cr content of 0.61%, which cannot satisfy the Mo content of 0.2 to 1.0% and the Cr content of 0.5% or less, which are required in the exemplary embodiment of the present invention. Since the Cr content increases instead of Mo, dual phase steel can be obtained. However, since Cr-based carbides are re-dissolved at a low temperature as compared with Mo-based carbides during annealing, they do not effectively promote the development of the [111] recrystallization texture. Further, since the comparative steel (13) has a very low r-value of 1.21, and martensite of 2.1 □, it does not satisfy the conditions of the inventive steel.

[87] The comparative steel (14) has the Sol.Al content that deviates from a range according to the exemplary embodiment of the present invention. Al disperses pearlite during hot rolling and causes the coarsening of martensite during annealing. The comparative steel (14) has the Al content of 0.04%, which is lower than the component according to the inventive steel. Therefore, the comparative steel (14) has a slightly low r-value of 1.31, and martensite is 1.8 □, which do not satisfy the condition according to the exemplary embodiment of the present invention.

[88] The comparative steel (15) has the Sol.Al content and the Mo content that deviate from ranges according to the inventive steel. The lack of Al does not allow the dispersion of pearlite during hot rolling and the coarsening of martensite during annealing. The lack of Mo does not allow the development of the [111] texture by Mo-based carbides during annealing. As a result, the comparative steel (15) has an r-value of 1.03, and martensite is very small, that is, 1.6 □.

[89] The steel kind (16) has a very high C content of 0.041%, and a Mo content of 0.07%, which deviate from the conditions according to the exemplary embodiment of the present invention. Since an excessive amount of carbon is added, the amount of martensite is very large. However, the effect of Mo is weak, the increases in the r-value cannot be expected.

[90]

[91]

[92]

Claims

[1] A dual phase steel sheet having excellent deep drawability, comprising by weight%:
C:0.01 to 0.03%, Si:0.3% or less, Mn:1.0 to 2.0%, P:0.01 to 0.06%, S:0.015% or less, soluble Al:0.2 to 0.8%, N:0.0030% or less, Mo:0.2 to 1.0%, Cr:0.5% or less, and B:0.0005 to 0.0015%, the balance Fe, and unavoidable impurities, wherein the dual phase steel sheet has a dual phase structure that includes martensite and ferrite.

[2] The dual phase steel sheet of claim 1, wherein the martensite has a size of 2.2 □ or more and a fraction of 2 to 5%.

[3] The dual phase steel sheet of claim 1, wherein the steel sheet includes Mo carbides.

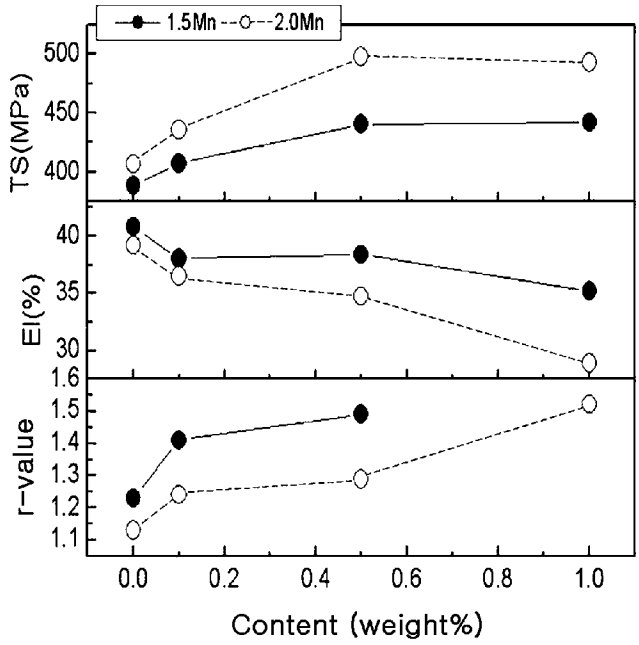
[4] The dual phase steel sheet of claim 1, the dual phase steel sheet is selected between a cold-rolled steel sheet and a plated steel sheet that has a hot dip galvanized layer formed at one or more surfaces thereof.

[5] The dual phase steel sheet of claim 1, wherein the steel sheet has a tensile strength of 440 to 490 MPa, an elongation of 32% or more, and an r-value of 1.4 or more.

[6] A method for manufacturing a dual phase cold-rolled steel sheet having excellent deep drawability, the method comprising:
homogenizing steel slabs containing, by weight%, C:0.01 to 0.03%, Si:0.3% or less, Mn:1.0 to 2.0%, P:0.01 to 0.06%, S:0.015% or less, soluble Al:0.2 to 0.8%, N:0.0030% or less, Mo:0.2 to 1.0%, Cr:0.5% or less, B:0.0005 to 0.0015, the balance Fe, and unavoidable impurities, at a temperature of 1200℃ or more, hot rolling the homogenized slabs at a finish rolling temperature of 900 to 950℃, and coiling the hot-rolled slabs at a temperature of 700 to 750℃ to obtain a hot-rolled steel sheet;
cold rolling the hot-rolled steel sheet at a reduction of 70 to 80%;
continuously annealing the cold-rolled steel sheet at a temperature of 800 to 850℃; and
temper rolling the continuously annealed steel sheet at a reduction ratio of 1.0%.

[7] The method of claim 6, wherein Mo carbides are included in the hot-rolled steel sheet.

[Fig. 1]


1.5Mn
2.0Mn
TS(MPa)
500
450
400
El(%)
40
35
30
r-value
1.6
1.5
1.4
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1.2
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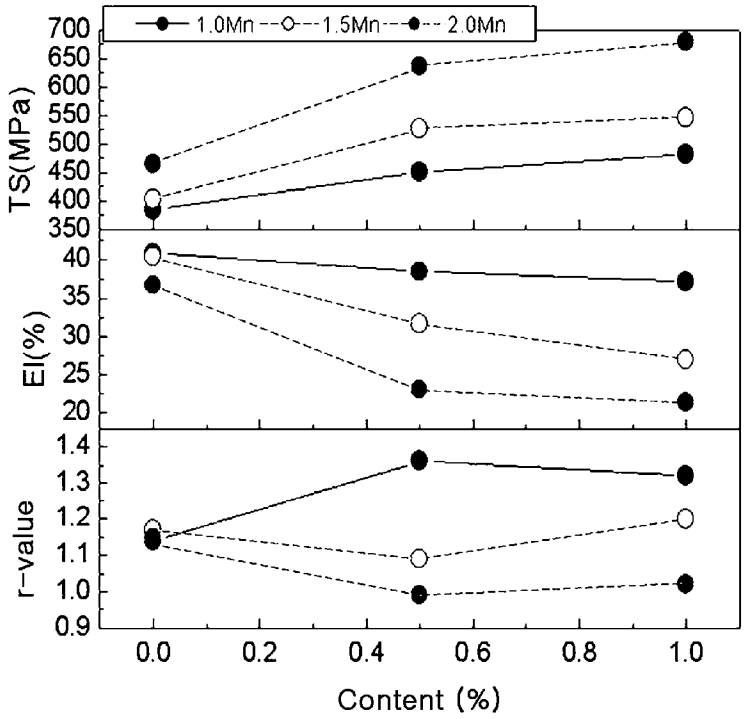
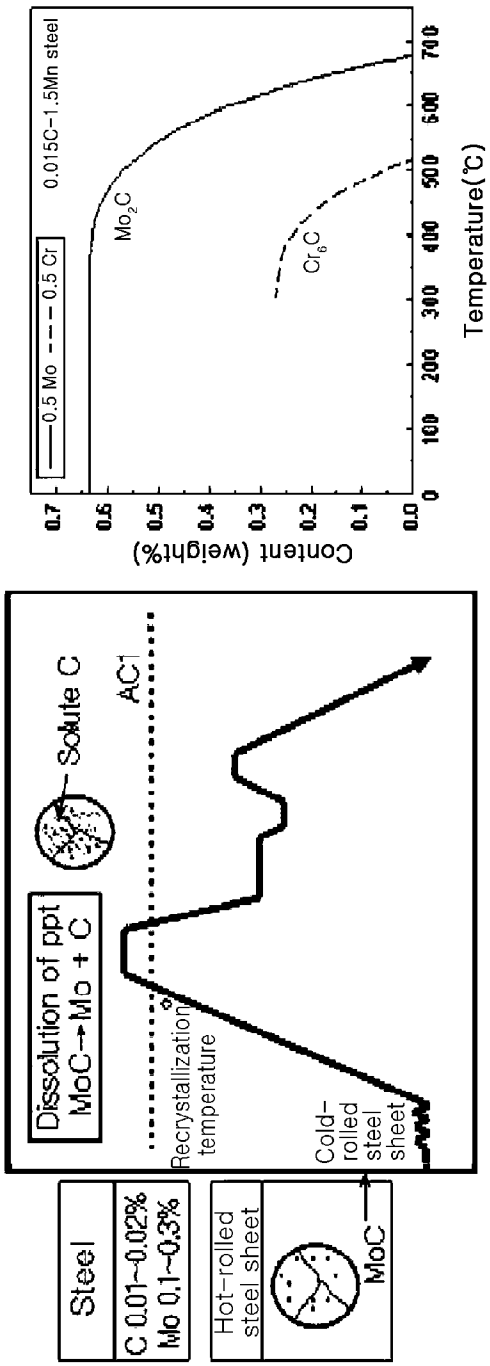
0.2
0.4
0.6
0.8
1.0
Content (weight%)

[Fig. 2]



[Fig. 3]


Content (weight%)
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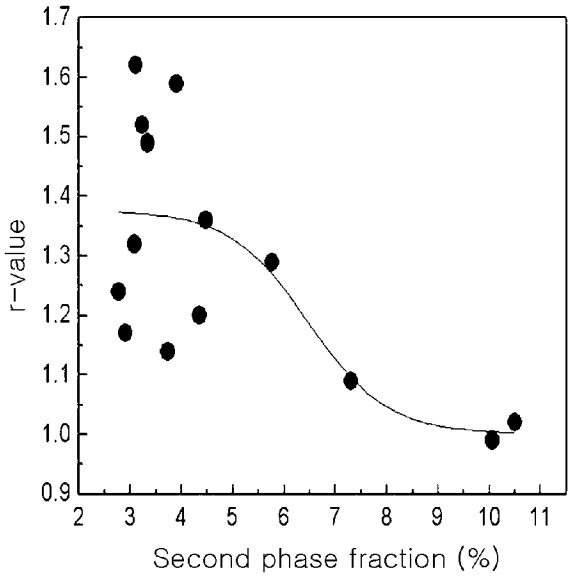
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.5 Mo
0.5 Cr
0.015C-1.5Mn steel
Mo_2C
Cr_6C
0
100
200
300
400
500
600
700
Temperature(℃)
Steel
C 0.01~0.02%
Mo 0.1~0.3%
Hot-rolled steel sheet
MoC
Cold-rolled steel sheet
Recrystallization temperature
Dissolution of ppt
MoC→Mo + C
Solute C
AC1

[Fig. 4]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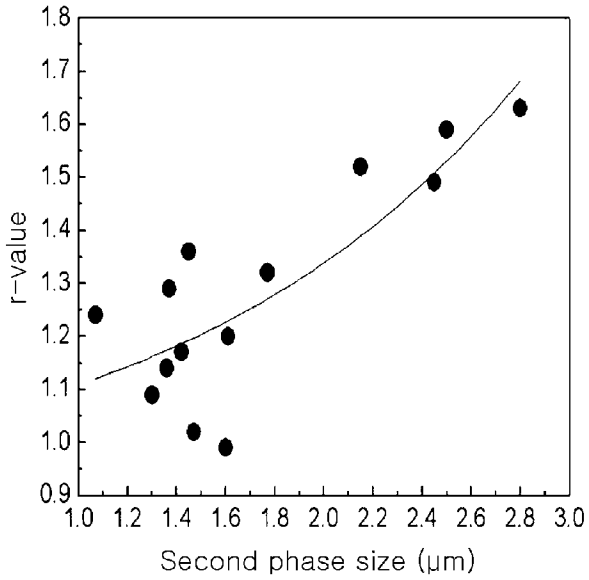
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
2
3
4
5
6
7
8
9
10
11
Second phase fraction (%)

[Fig. 5]


r-value
Second phase size (μm)
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1.7
1.6
1.5
1.4
1.3
1.2
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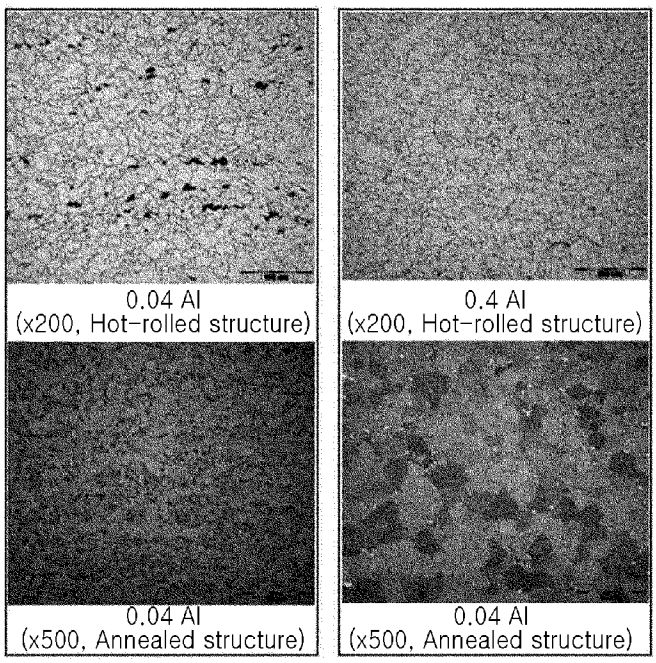
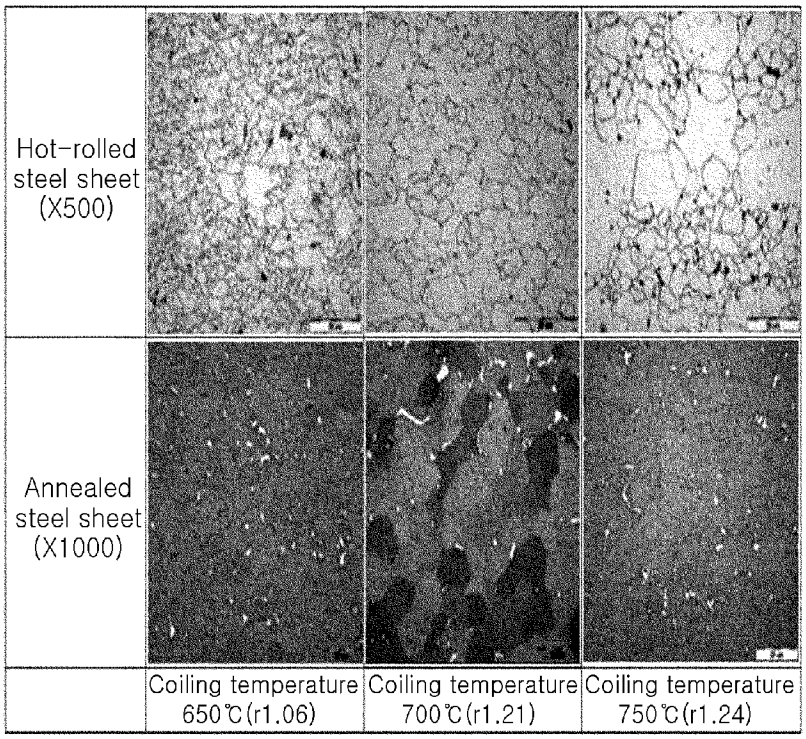
1.0
0.9
1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0

[Fig. 6]


0.04 Al
(x200, Hot-rolled structure)
0.4 Al
(x200, Hot-rolled structure)
0.04 Al
(x500, Annealed structure)
0.04 Al
(x500, Annealed structure)

[Fig. 7]


Hot-rolled steel sheet (X500)
Annealed steel sheet (X1000)
Coiling temperature 650℃(r1.06)
Coiling temperature 700℃(r1.21)
Coiling temperature 750℃(r1.24)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2007/006813

A. CLASSIFICATION OF SUBJECT MATTER

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)

IPC 8 C21D 8/00, C21D 9/46, C22C38/00, C22C 38/00, C23C 2/06, C23C 2/28.

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 since 1975.
Japanese Utility models and applications for Utility models since 1975.

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

eKIPASS(KIPO internal) & keywords: deep drawability, dual phase steel, ferrite, martensite and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003-0129444 A1 (SAIJI MATSUOKA et al.) 10 July 2003 See the abstract, claims 1, 5, and paragraphs [0089], [0090], [0097] - [120].	1 - 7
A	WO 2006-001583 A1 (POSCO) 5 January 2006 See the abstract, and claims 1, 45.	1 - 7
A	EP 1362930 A1 (NIPPON STEEL CORPORATION) 19 November 2003 See the abstract, and claims 5 - 8, 15 - 19.	1 - 7
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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