Abstract: There are provided a hot rolled steel sheet that has superior hot press forming property and high tensile strength and is used for structural members and their parts of automobiles and the like, a formed article, and a method for manufacturing the hot rolled steel sheet and the formed article. The hot rolled steel sheet having superior hot press forming property and high tensile strength includes, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, Ni: 0.1% to 0.5%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1%, and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities, wherein a structure of the hot rolled steel sheet includes 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite, or includes 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite and martensite.
Description

HOT ROLLED STEEL SHEET HAVING SUPERIOR HOT PRESS FORMING PROPERTY AND HIGH TENSILE STRENGTH, FORMED ARTICLE USING THE STEEL SHEET AND METHOD FOR MANUFACTURING THE STEEL SHEET AND THE FORMED ARTICLE

Technical Field

The present invention relates to a hot rolled steel sheet used for structural members and their parts of automobiles and the like and a method for manufacturing the same, and more particularly, to a hot rolled steel sheet having superior hot press forming property and high tensile strength and a formed article using the hot rolled steel sheet, and a method for manufacturing the hot rolled steel sheet and the formed article.

Background Art

Recently, structural members and their parts of automobiles have been manufactured with a lighter-weight scale and high tensile strength in the automobile industries so as to comply with the environmental regulations and secure the passenger safety. Therefore, there have been attempted to develop a method for manufacturing a steel sheet having superior formability and high tensile strength for the purpose of providing the sheet for automobiles with a high tensile strength.

In order to achieve the superior formability and high tensile strength, a hot press forming method has been widely used. High-strength steel sheet used in the hot press forming method is a cold rolled steel sheet, which is prepared by heating a steel sheet to a high temperature, keeping the steel sheet to the high temperature, press-forming the steel sheet into an automobile structural member in a die having a certain shape and simultaneously quenching the automobile structural member in the die flowing in a cooling water, thus to produce a hot press formed part having high tensile strength.

However, this hot press forming method has problems in that a burden on the cost is inevitably high since its productivity is low and the cold rolled steel sheet used in the hot press forming method is expensive. Also, the hot press formed parts prepared at a low cooling rate have different hardness according to their regions due to the insufficient hardenability of the cold rolled steel sheet.

[1] The present invention relates to a hot rolled steel sheet used for structural members and their parts of automobiles and the like and a method for manufacturing the same, and more particularly, to a hot rolled steel sheet having superior hot press forming property and high tensile strength and a formed article using the hot rolled steel sheet, and a method for manufacturing the hot rolled steel sheet and the formed article.

[2] Background Art

[3] Recently, structural members and their parts of automobiles have been manufactured with a lighter-weight scale and high tensile strength in the automobile industries so as to comply with the environmental regulations and secure the passenger safety. Therefore, there have been attempted to develop a method for manufacturing a steel sheet having superior formability and high tensile strength for the purpose of providing the sheet for automobiles with a high tensile strength.

[4] In order to achieve the superior formability and high tensile strength, a hot press forming method has been widely used. High-strength steel sheet used in the hot press forming method is a cold rolled steel sheet, which is prepared by heating a steel sheet to a high temperature, keeping the steel sheet to the high temperature, press-forming the steel sheet into an automobile structural member in a die having a certain shape and simultaneously quenching the automobile structural member in the die flowing in a cooling water, thus to produce a hot press formed part having high tensile strength.

[5] However, this hot press forming method has problems in that a burden on the cost is inevitably high since its productivity is low and the cold rolled steel sheet used in the hot press forming method is expensive. Also, the hot press formed parts prepared at a low cooling rate have different hardness according to their regions due to the insufficient hardenability of the cold rolled steel sheet.
In order to solve the above problems, conventional representative technologies include the methods proposed in Japanese Patent Laid Open Publication Nos.2006-126733, 2006-152427, 2006-213959, etc.

First, the Japanese Patent Laid Open Publication No.2006-126733 proposes a method for manufacturing a cold rolled steel sheet that has a high tensile strength and is used for a hot press forming process. Here the method includes: adding the following elements including, % by weight: C: 0.05 to 0.4%, Mn: 0.01 to 4.0%, Cr: 0.005 to 5.0%, either or both Mo or/and Nb: 0.1 to 3.0% and an alloying element such as Ti, V, W, B and Ni; pressing a steel sheet containing N: 0.01% or less at a high temperature to form a cold rolled steel sheet having 60% or more of a martensite structure.

Also, the Japanese Patent Laid Open Publication No.2006-152427 proposes a method for manufacturing a cold rolled steel sheet, including: adding the following elements including, % by weight: C: 0.25 to 0.45%, Mn+Cr: 0.5 to 3.0% and an alloying element such as Mo, Nb, Ti, V and B, maintaining a steel sheet containing N: 0.002% or less under a high temperature, and cooling the steel sheet to the Ms temperature at a cooling rate of 10 to 500°C/s.

Furthermore, the Japanese Patent Laid Open Publication No.2006-213959 proposes a cold rolled steel sheet for a hot press forming process, which is substantially similar to those of the two above-mentioned patents.

Disclosure of Invention

Technical Problem

The present invention is designed to solve the problems of the prior art, and therefore it is an object of the present invention to provide a hot rolled steel sheet having superior hot press forming property and high tensile strength, a formed article using the hot rolled steel sheet, and a method for manufacturing the hot rolled steel sheet and the formed article.

Technical Solution

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

According to an aspect of the present invention, there is provided a hot rolled steel sheet having superior hot press forming property and high tensile strength, including,
by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities, wherein a structure of the hot rolled steel sheet includes 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite, or includes 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite and martensite.

[22]
According to another aspect of the present invention, there is provided a formed article including, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities, wherein a structure of the formed article includes 80% or more of martensite and 20% or less of at least one selected from the group consisting of bainite, pearlite and ferrite, based on the area fraction of the formed article, and has a tensile strength of 1470 MPa or more.

[24]
According to an aspect of the present invention, there is provided a method for manufacturing a hot rolled steel sheet having superior hot press forming property and high tensile strength. Here, the method includes: hot-rolling a steel slab at a temperature greater than an Ar3 transformation point, the steel slab including, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities; cooling the hot-rolled steel slab at a cooling rate of 10°C/s or more; and coiling the cooled hot-rolled steel slab at a bainite transformation start temperature (Bs) or below.

[26]
According to still another aspect of the present invention, there is provided a method for manufacturing a formed article. Here, the method includes: maintaining the hot rolled steel sheet, as prepared in the method according to one exemplary embodiment of the present invention, at a temperature equal to or above the Ac3 transformation
point for a predetermined period; hot-press forming the hot rolled steel sheet; and
cooling the hot-press formed steel sheet to a martensite transformation start
temperature (Ms) at a cooling rate of 1°C/sec or more.

Advantageous Effects

In accordance with the present invention, the hot press formed structural member
having superior tensile strength may be obtained from the hot rolled steel sheet even
when the hot rolled steel sheet is cooled at a lower cooling rate than the cold rolled
steel sheet for a conventional hot press forming process. Also, the present invention
provides a hot rolled steel sheet having high economical efficiency and high tensile
strength, compared to the cold rolled steel sheet, and the formed article using the hot
rolled steel sheet may be provided.

Brief Description of Drawings

FIG. 1 is a schematic view illustrating the control of continuous phase transformation
by the addition of alloying elements. Here, FIG. IA shows the control of continuous
phase transformation of a conventional steel, and FIG. IB shows the control of
continuous phase transformation of a steel sheet containing an added alloying element.

Best Mode for Carrying out the Invention

Hereinafter, exemplary embodiments of the present invention will be described in
detail. In this overall specification, the term '% percent (%)' used in the exemplary em-
bellishments represents '% by weight', unless indicated otherwise.

The steel sheet according to one exemplary embodiment of the present invention
includes, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or
less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001
to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%,
Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group
consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005 to
2.0%, and the balance of iron (Fe) and other inevitable impurities. Here, the
components of the hot rolled steel sheet and their numerical limitations are described
in detail, as follows.

A content of carbon (C) is defined to 0.1 to 0.5%. The carbon (C) is an element that
is essential to enhance the strength of a steel sheet. In order to obtain a martensite
phase having high tensile strength from the hot press formed part, the lower limit of the
C content is set to 0.1%. When the carbon (C) is added in a content greater than 0.5%,
the weldability of the steel sheet may be deteriorated, which leads to an increase in poor products in the assembly for automobiles, and the strength of the steel sheet is excessively increased during a plating process, which makes it difficult to thread the steel sheet. Therefore, the upper limit of the C content is defined to 0.5%.

Manganese (Mn) is an element that gives a very high solid strengthening effect to a steel sheet, and simultaneously delays the transformation of austenite into a ferrite microstructure and lowers an Ar3 temperature as well. When a content of the added manganese (Mn) is too low, it is difficult to press-forming process in an austenitic single phase region at a high temperature during a hot press forming process, whereas when the content of the added manganese (Mn) is too high, problems associated with the manufacture of a hot rolled coil may be caused due to the deteriorated weldability of the steel sheet and an increase in the rolling load during the hot rolling process. Therefore, the Mn content is defined to 1.0 to 3.0%.

Silicon (Si) is an element that functions to improve a ferrite strength of a steel sheet by means of the solid strengthening. However, when the silicon (Si) is added in a large amount, scale defects in the steel sheet may be increased, which leads to the deteriorated surface quality and coatability of the steel sheet. Therefore, the upper limit of the Si content is defined to 0.5%.

Tungsten (W) is a unique element that may improve the heat-treatment hardenability and heat resistance of a steel sheet during the hot press forming process. Also, the tungsten (W) is one of important elements used in the present invention since it functions to suppress the grain growth in re-heating the steel sheet, and has an effect to reduce a grain size. However, when a content of the added W exceeds 0.1%, the above-mentioned effects may be saturated, and the manufacturing cost may also be high due to the use of the expensive W. Therefore, the upper limit of the W content is defined to 0.1%.

Aluminum (Al) is added for two purposes. One purpose is to remove oxygen from steel so as to prevent formation of a non-metallic inclusion during coagulation, and the other is to refine a size of grains by fixing nitrogen (N) in the steel in the form of AlN. As a result, Al should be also added within a suitable content range. In this case, when the Al content is too low, the addition effect of Al may not be achieved. On the contrary, when the very high Al content results in an excessively increase in the strength of the steel sheet and an increase in the steel-making factors. Therefore, the Al content is defined to 0.01 to 0.1%.
Sulfur (S) is an impurity that increases an amount of precipitates by its precipitation in the form of MnS. Therefore, it is necessary to adjust the S content to the extent as low as possible. Then, the upper limit of the S content is defined to 0.03%. Not to specify the lower limit of the S content is why the formability of the steel sheet is improved as the S content decreases due to the same reasons as described above.

Phosphorus (P) adversely affects the weldability and a hot rolling process when the phosphorus (P) is added in an excessive amount. Also, the excessive phosphorus (P) may degrade the workability of a steel sheet. Therefore, the upper limit of the P content is defined to 0.1%.

Nitrogen (N) is one of very important elements used in the present invention. The nitrogen (N) is a solid strengthening element and an element that forms nitrides by binding to a component such as Ti, Nb, V, Al, etc. In accordance with the present invention, a sufficient amount of N is added to improve the heat-treatment properties and strength of a steel sheet. When the N content is less the 0.01%, it is impossible to expect these effects, whereas when the N content exceeds 0.1%, problems associated with the steel-making and casting processes may be caused. Therefore, the N content is defined to 0.01 to 0.1%.

Boron (B) functions to suppress the transformation of austenite into a ferrite or bainite microstructure by segregating from grain boundaries to reduce a grain boundary energy. When a content of the added boron (B) is too low, it is impossible to secure a sufficient addition effect of B, whereas when the content of the added boron (B) is too high, the grain boundary precipitation of a large amount of B complexes leads to the deteriorated toughness and degraded hardenability of the steel sheet. Therefore, the B content is defined to 0.001 to 0.01%.

The hot rolled steel sheet according to one exemplary embodiment of the present invention includes at least one element selected from the group consisting of titanium (Ti), niobium (Nb) and vanadium (V).

The titanium (Ti), niobium (Nb) and vanadium (V) are elements that are effective to enhance the strength of a steel sheet by facilitating the precipitation of carbonitrides, and improve the toughness of the hot press formed structural parts by the refinement of grains. When each of the components is added in a content of less than 0.001%, it is possible to obtain such effects, whereas when each of the components is added in a
content of greater than 0.1%, the manufacturing cost may be high and problems associated with the hot-rolling process may be caused by the precipitation of excessive carbonitrides.

[57]

[58] Also, the hot rolled steel sheet according to one exemplary embodiment of the present invention includes at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005 to 2.0%.

[59]

[60] Molybdenum (Mo) aids to prepare a hot press formed part having high tensile strength since it functions to highly improve the hardenability of a steel sheet to facilitate formation of a martensite structure after the hot press forming process. Also, the molybdenum (Mo) enhances the strength of the steel sheet by facilitating the precipitation of fine carbides, and improves the toughness of the steel sheet by refining grains. In order to achieve these above effects, the lower limit of the Mo content is defined to 0.01%. Here, the Mo content reaches 1.5%, the above effects are saturated, and the steel-making cost may be high. Therefore, the upper limit of the Mo content is defined to 1.5%.

[61]

[62] Chromium (Cr) is an element that improves the hardenability of a steel sheet and facilitates formation of carbides, and an important element to prepare a hot press formed part having high tensile strength. In order to achieve these above effects, the lower limit of the Cr content is defined to 0.01%. When the Cr content exceeds 1.5%, the above effects are saturated, and the steel-making cost may be high. Therefore, the upper limit of the Cr content is defined to 1.5%.

[63]

[64] Copper (Cu) is an element that is effective to enhance the strength of a steel sheet by facilitating formation of fine precipitates. When the Cu content is less than 0.005%, it is impossible to achieve the above effects, whereas when the Cu content exceeds 1.0%, the workability of the steel sheet may be deteriorated. Therefore, the Cu content is defined to 0.005 to 1.0%.

[65]

[66] Nickel (Ni) is an element that is effective to improve heat-treatment property of a steel sheet by improving the hardenability of the steel sheet in addition to the solid strengthening effect. When a content of the nickel (Ni) is less than 0.005%, it is impossible to achieve the above effects, whereas when the content of the nickel (Ni) exceeds 2.0%, the workability of the steel sheet may be deteriorated, scale defects may be caused during a hot rolling process, and the manufacturing cost may be increased. Therefore, the Ni content is defined to 0.005 to 2.0%.
FIG. 1 schematically shows the changes in continuous cooling phase transformation by addition of an alloying element. FIG. IA is a schematic view illustrating a continuous cooling state of a microstructure of a hot rolled steel sheet obtained when a conventional steel is cooled from a high temperature (for example, a rolling finish temperature) to a room temperature at different cooling rates (cooling rates: 1 > 2 > 3), and FIG. IB is a schematic view illustrating a continuous cooling state of a microstructure of hot rolled steel sheet when an alloying element is added to a conventional steel so as to improve curability of the conventional steel.

As shown in FIG. IA, a martensite single phase is formed when a steel sheet is cooled at a cooling rate of 1. a ferrite+bainite+martensite structure is formed when a steel sheet is cooled at a cooling rate of 2, and a ferrite + pearlite + bainite + martensite structure is formed when a steel sheet is cooled at a cooling rate of 3.

As shown in FIG. IB, it may be revealed that ferrite, pearlite, bainite transformation curves move rightward along the time axis with respect to the transformation curves of FIG. IA, which indicates that the ferrite, pearlite, bainite transformation is delayed. Due to the effects of the alloying element, a microstructure different from the conventional steel is obtained even when the steel is cooled at the same cooling rate. That is to say, as shown in FIG. IB, a martensite microstructure is obtained when a steel sheet is cooled at a cooling rate of 1, a martensite microstructure is also obtained when a steel sheet is cooled at a cooling rate of 2, and a bainite and martensite microstructure is obtained when a steel sheet is cooled at a cooling rate of 3. Accordingly, it is possible to achieve the increase in the cooling rate without an additional process of increasing the cooling rate.

In accordance with the present invention, the increase in the cooling rate may be achieved without an additional process of increasing the cooling rate by adding an alloying element to a conventional steel to improve the hardenability of a steel sheet.

The hot rolled steel sheet according to one exemplary embodiment of the present invention has a microstructure including 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite, or a microstructure including 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite and martensite.

When the microstructure includes a martensite structure, the bainite structure is preferably present in an area fraction of 50% or more and the martensite structure is
preferably present in an area fraction of 30% or less.

Hereinafter, the method for manufacturing a steel sheet according to one exemplary embodiment of the present invention is described in more detail.

The steel slab having the above-mentioned composition is re-heated using one of conventional methods in the present invention, and hot rolled. Then, the hot rolling is finished at a temperature above the Ar3 transformation point as a hot rolling finish temperature, and the hot-rolled steel slab was cooled at a cooling rate of 10°C/s or more and coiled below a bainite transformation start temperature (Bs) (generally below 600°C) to prepare a hot rolled steel sheet having superior hot press forming property and high tensile strength.

To define the hot rolling finish temperature to the Ar3 transformation point or above is to prevent rolling at a two-phase region. In this case, when an inventive steel is rolled at a two-phase region, a large amount of carbide-free proeutectoid ferrite is formed, which makes it impossible to obtain a bainite structure over the entire structure, as required in the present invention.

Also, to define the cooling rate to 10°C/s or more after the hot rolling process is to allow a large amount of ferrite and pearlite to precipitate at a cooling rate of 10°C/s or less, which makes it impossible to obtain a hot-rolled bainite structure, or a duplex structure of bainite and martensite, as required in the present invention. However, there is no upper limit on the cooling rate. This is why it is easier to obtain a bainite and/or martensite structure as the cooling rate gets faster and faster, as shown in FIG. 1.

In addition, a coiling temperature is defined to a bainite transformation start temperature (Bs) or below in the hot coiling process. This is why it is impossible to obtain a desired low-temperature structure in the present invention since the coiling at a temperature greater than the Bs induces the pearlite transformation. The lower limit of the coiling temperature is not defined since it is advantageous to obtain a fine bainite or martensite structure required in the present invention when the hot-rolled steel sheet may be easily coiled by a downcoiler having excellent performances.

A formed article having a martensite area fraction of 80% or more and a tensile strength of 1470 MPa or more may be obtained by keeping the hot rolled steel sheet thus prepared at a temperature above the Ac3 transformation point, subjecting the hot rolled steel sheet to a hot press forming process, and quenching the hot press-formed
steel sheet to a martensite transformation start temperature (Ms) at a cooling rate of 1°C/s or more.

[91] A structure of the formed article includes 80% or more of a martensite structure and 20% or less area fraction of at least one structure selected from the group consisting of bainite, pearlite and ferrite structures, based on the.

[93] The hot rolled steel sheet according to one exemplary embodiment of the present invention may be coiled even at a relatively low cooling rate of 1 to 30°C/s to prepare a formed article having 80% or more martensite area fraction and a tensile strength of 1470 MPa or more.

[95] When the cooling rate is slower than 1°C/s after the hot press forming process, a sufficient martensite area fraction may not be secured since austenite is transformed into a high-temperature phase such as ferrite and pearlite, which makes it difficult to obtain a formed article having a tensile strength of 1470 MPa or more. Therefore, it is desirable to define the lower limit of the cooling rate to 1°C/s. However, the swifter the cooling rate is, the more desirable it is to secure the martensite structure. Therefore, the upper limit of the cooling rate does not need to be defined.

[97] **Mode for the Invention**

[98] Hereinafter, exemplary embodiments of the present invention are described in more detail.

[99]

[100] (EXAMPLES)

[101] A steel ingot having a composition as listed in the following Table 1 was prepared by a vacuum-induction melting process. Here, the prepared steel ingot has a thickness of 60 mm and a width of 175 mm. The steel ingot was re-heated at 1200°C for 1 hour, and hot-rolled so that it can have a hot rolling thickness of 1.6 mm. A hot rolled hot rolling finish temperature was above the Ar3 transformation point. Then, a hot coiling process was simulated by cooling the re-heated steel ingot at a ROT cooling rate of 5°C/s and 50°C/s to a desired hot coiling temperature, keeping the cooled steel ingot for 1 hour in a furnace pre-heated to 400 to 650°C and cooling the steel ingot in the furnace. The hot press forming simulation was carried out with a dilatometer by cooling a steel ingot at a cooling rate of 20°C/s and measuring hardness of the steel ingot to calculate a tensile strength of the steel ingot. The results are listed in the following Table 2.
Among the steels as listed in the following Table 1, the Steels 1, 2 and 3 belong to the scope of the present invention, but the Steels 4 and 5 are out of the component condition of the Inventive steels. The manufacturing conditions of the steels as listed in Table 1, for example, a cooling rate (ROT cooling rate) after the finish rolling process, the presence of proeutectoid ferrite according to the coiling temperature, and a tensile strength calculated after the final hot press forming simulation, are listed in the following Table 2.

The presence/absence of the proeutectoid ferrite/pearlite as listed in the following Table 2 are expressed by 'yes' when a fraction of the proeutectoid ferrite/pearlite exceeds 10%, and expressed by 'no' when a fraction of the proeutectoid ferrite/pearlite accounts for 10% or less. However, only the steels that do not have proeutectoid ferrite/pearlite correspond to the Inventive steels.

### Table 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>Chemical composition (wt%)</th>
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<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>0.22</td>
</tr>
<tr>
<td>2</td>
<td>0.21</td>
</tr>
<tr>
<td>3</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>0.07</td>
</tr>
<tr>
<td>5</td>
<td>0.23</td>
</tr>
</tbody>
</table>

### Table 2
As listed in Table 2, it was revealed that a bainite structure containing fine carbides is formed in the case of the Inventive steels that are prepared by quenching the Steels 1, 2 and 3 at a ROT cooling rate (cooling rate: 50°C/s) and coiling the Steels 1, 2 and 3 at a temperature below the Bs point. Therefore, it was shown that the Inventive steels have a tensile strength of 1470 MPa or more since the martensite structure is easily formed at a relatively low cooling rate (20°C/s) after the hot press forming simulation.

On the contrary, a bainite structure having a mixed proeutectoid ferrite/pearlite structure was obtained even when the Steels 4 and 5 was quenched at a ROT cooling rate and their coiling temperature was controlled. On the basis of the above result, the steels having a tensile strength of 1470 MPa were not obtained when the Steels 4 and 5 was cooled at a low cooling rate of 20°C/s after the hot press forming simulation.

When the Steels 1, 2 and 3 were quenched at a ROT cooling rate but coiled at a temperature above the Bs point, a ferrite+pearlite structure was formed as the final hot

<table>
<thead>
<tr>
<th>St eels</th>
<th>Steel-man ufacturing conditions</th>
<th>ROT cooling rate (°C/s)</th>
<th>Coiling Temp. (°C)</th>
<th>Presence of proeutectoid ferrite/pearlite</th>
<th>Tensile strength (MPa) after hot press forming simulation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
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rolling structure, and the steels had a low tensile strength of approximately 1320 MPa after the hot press forming simulation.  

[115] Also, the Steels 1, 2 and 3 are maintained to a coiling temperature below the Bs point but the cooling rate is less than the cooling rate required in the present invention, a duplex structure of ferrite/pearlite + bainite appeared over the steels, and the steels had a tensile strength of less than 1470 MPa after the hot press forming process.  

[117] The presence/absence of the proeutectoid ferrite is dependent on the case that the hot rolling finish process is carried out at a temperature below the Ar3 transformation point, the cooling rate (ROT cooling rate) after the finish rolling process, and the coiling temperature.  

[119] That is to say, the Ar3 transformation temperature depends mainly on the cooling rate after the cooling of the steel from an austenite temperature range, but the rolling at the Ar3 transformation point or below represents the production of proeutectoid ferrite, which leads to the non-uniform microstructure in the steel.  

[121] And, it was seen that the slower the ROT cooling rate is, the more the transformation into ferrite and pearlite is promoted, and the faster the cooling rate is, the transformation into bainite and martensite occurs, as shown in FIG. 1.  

[123] Also, it was revealed that the lower the coiling temperature at which the hot-rolled transformation is finished is, the lower the possibility to form proeutectoid ferrite is. This is in accord with the fact that a larger fraction of the proeutectoid ferrite is formed at a higher coiling temperature even under the same conditions such as the composition and the cooling rate, as listed in Table 2.  

[125] Furthermore, the present invention intended to secure a hot rolled steel sheet having a high tensile strength of 1470 MPa or more even when the hot rolled steel sheet was cooled at a low cooling rate after the hot press forming process. Therefore, since the formation of the proeutectoid ferrite and pearlite structures is suppressed and the formation of the bainite or martensite structure is induced in the hot rolled steel sheet, the carbides may be homogeneously dissolved more quickly when the hot rolled steel sheet is heated and maintained to the temperature greater than the Ac3 transformation point, and it is also possible to achieve the above objects by preventing the fine segregation from an inner part of the hot rolled plate.
Claims

[1] A hot rolled steel sheet having superior hot press forming property and high tensile strength, comprising, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities, wherein a structure of the hot rolled steel sheet comprises 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite, or comprises 10% or less of proeutectoid ferrite, 10% or less of pearlite and the balance of bainite and martensite.

[2] A formed article, comprising, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities, wherein a structure of the formed article comprises 80% or more of martensite and 20% or less of at least one selected from the group consisting of bainite, pearlite and ferrite, based on the area fraction of the formed article, and has a tensile strength of 1470 MPa or more.

[3] A method for manufacturing a hot rolled steel sheet having superior hot press forming property and high tensile strength, the method comprising:
hot-rolling a steel slab at a temperature greater than an Ar₃ transformation point, the steel slab comprising, by weight: C: 0.1 to 0.5%, Mn: 1.0 to 3.0%, Si: 0.5% or less, W: 0.1% or less, N: 0.01 to 0.1%, Al: 0.01 to 0.1%, S: 0.03% or less, P: 0.1% or less and B: 0.001 to 0.01%, at least one element selected from the group consisting of Ti: 0.001 to 0.1%, Nb: 0.001 to 0.1% and V: 0.001 to 0.1%, at least one element selected from the group consisting of Mo: 0.01 to 1.5%, Cr: 0.01 to 1.5%, Cu: 0.005 to 1.0% and Ni: 0.005-2.0%, and the balance of iron (Fe) and other inevitable impurities;
cooling the hot-rolled steel slab at a cooling rate of 10°C/s or more; and
coiling the cooled hot-rolled steel slab at a bainite transformation start temperature (Bs) or below.

[4] A method for manufacturing a formed article, comprising:
maintaining the hot rolled steel sheet, as prepared in the method as defined in claim 3, at a temperature equal to or above the Ac3 transformation point for a predetermined period;
hot-press forming the hot rolled steel sheet; and
cooling the hot-press formed steel sheet to a martensite transformation start temperature (Ms) at a cooling rate of 1°C/sec or more.
A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/00(2006.01)

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 B21D 5/01, B21D 22/20, C21D 1/02, C21D8/02, C21D 9/46, C22C 38/00, C22C38/04, C22C 38/14, C22C 38/54, C22C38/58

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 a hot rolled steel sheet, hot press forming property, and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C

See patent family annex

* Special categories of cited documents
  *A* document defining the general state of the art which is not considered to be of particular relevance
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  *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
  *O* document referring to an oral disclosure, use, exhibition or other means
  *P* document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search: 18 MARCH 2009 (18.03.2009)

Date of mailing of the international search report: 18 MARCH 2009 (18.03.2009)

Name and mailing address of the ISA/KR

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Facsimile No 82-42-472-7140

Authorized officer

LEE, SUNG JOON

Telephone No 82-42-481-5530

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