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(54) **HIGH PERFORMANCE STEEL BAR AND METHOD FOR MANUFACTURING HIGH PERFORMANCE STEEL BAR**

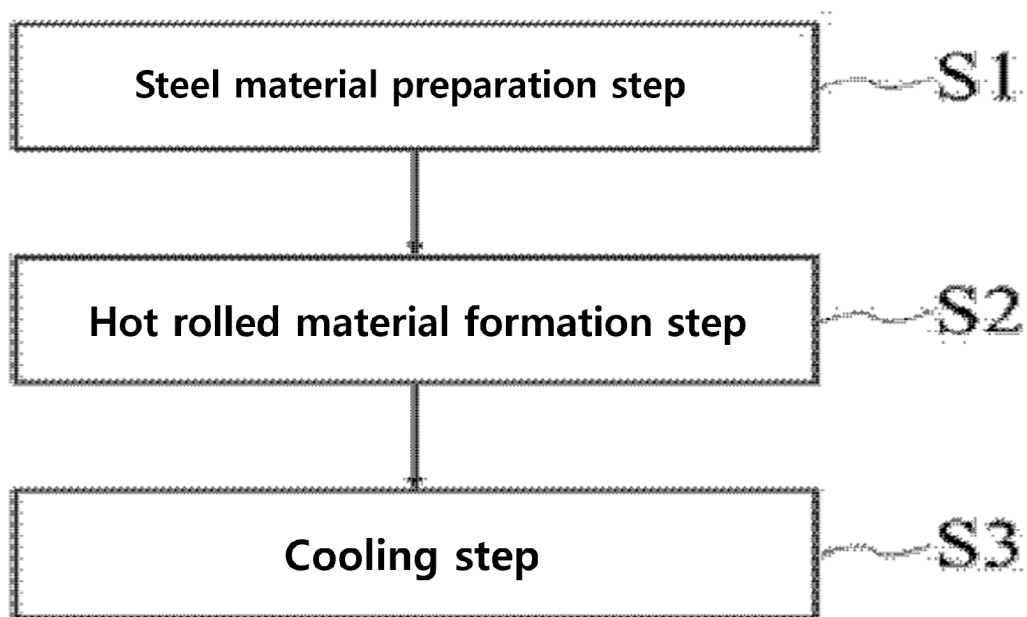
(57) A high-performance steel bar, according to one embodiment of the present invention, includes 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and the balance of iron (Fe) and inevitable impurities and satisfies Formula 1 below, in which the yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more.

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times \text{Si}(\text{wt}\%) + 81.40 \times \text{Mn}(\text{wt}\%) + 94.51 \times \text{Ni}(\text{wt}\%) + 202.33 \times \text{Cr}(\text{wt}\%) + 5228.70 \times \text{Nb}(\text{wt}\%) + 2256.36 \times \text{V}(\text{wt}\%) \geq 595.01$$

[Formula 1]

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[Fig. 1]



Description**[TECHNICAL FIELD]**

[0001] The present invention relates to a high-performance steel bar and a manufacturing method therefor.

[BACKGROUND ART]

[0002] A deformed steel bar or rebar is an elongated steel material used for reinforcing concrete and has a strong adhesion with concrete and compensates for the concrete vulnerable to the tension, thereby reducing a crack width when a concrete crack occurs. For these advantages, it is widely used in construction and civil engineering sites. For example, the deformed steel bar or rebar is used as pivotal materials in the construction of bridges, large offshore structures, underground structures, and storage tanks.

[0003] Recently, due to environmental concerns and the shift in the domestic energy policy, interest in the natural gas has been increasing. The natural gas is liquefied below -170°C to be transported in the form of liquefied natural gas (LNG) and the transported liquefied natural gas is stored in an LNG tank. The LNG tank for storing the LNG liquefied at a temperature below -170°C requires a specialized structure and a material which withstands the temperature around -170°C .

[0004] The LNG tank is mainly configured by an inner tank and an outer tank and the inner tank which is in contact with LNG is configured by 9% Ni steel sheet which withstands -170°C environment and the outer tank is configured by reinforced concrete. The deformed steel bar used for the LNG storage tank requires a rebar which withstands -170°C to maintain the structure without undergoing brittle fracture even by rapid temperature drop.

[0005] Accordingly, development of a high-performance steel bar which has excellent strength even in the environment having a temperature of -170°C or lower and does not undergo the brittle fracture and a manufacturing method therefor is demanded.

[DISCLOSURE]**[TECHNICAL PROBLEM]**

[0006] In order to solve the problem of the related art as described above, an object of the present invention is to provide a high-performance steel bar which is capable of ensuring a yield strength and notch sensitivity in a low temperature environment and a manufacturing method for a steel bar.

[0007] Objects of the present invention are not limited to the above-mentioned objects, and other objects, which are not mentioned above, can be clearly understood by those skilled in the art from the following descriptions.

[TECHNICAL SOLUTION]

[0008] A high-performance steel bar according to one embodiment of the present invention includes: 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chromium (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and the balance of iron (Fe) and inevitable impurities and satisfies Formula 1 below, and the yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more.

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times Si(\text{wt}\%) + 81.40 \times Mn(\text{wt}\%) + 94.51 \times Ni(\text{wt}\%) + 202.33 \times Cr(\text{wt}\%) + 5228.70 \times Nb(\text{wt}\%) + 2256.36 \times V(\text{wt}\%) \geq 595.01 \quad [\text{Formula 1}]$$

[0009] The tensile strength (TS_{un}) of the unnotched specimen at -170°C may be 690 MPa or more.

[0010] The tensile strength (TS_{un}) of the unnotched specimen at -170°C may be 1.15 times or more the yield strength (YS_{un}) of an unnotched specimen at -170°C .

[0011] The tensile strength (TS_n) of the notch specimen at -170°C may be 600 MPa or more.

[0012] The tensile strength (TS_n) of the notch specimen at -170°C may be equal to or more than the yield strength (YS_{un}) of an unnotched specimen at -170°C .

[0013] According to an aspect of the present invention, a high-performance steel bar includes 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or

less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and the balance of iron (Fe) and inevitable impurities, the yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more, and the tensile strength (TS_n) of a notched specimen at -170°C is 600 MPa or more.

[0014] The tensile strength (TS_n) of the notch specimen at -170°C may be equal to or more than the yield strength (YS_{un}) of an unnotched specimen at -170°C .

[0015] Further, the high-performance steel bar according to the embodiment of the present invention may satisfy the following Formula 1.

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times Si(\text{wt}\%) + 81.40 \times Mn(\text{wt}\%) + 94.51 \times Ni(\text{wt}\%) + 202.33 \times Cr(\text{wt}\%) + 5228.70 \times Nb(\text{wt}\%) + 2256.36 \times V(\text{wt}\%) \geq 595.01 \quad [\text{Formula 1}]$$

[0016] The tensile strength (TS_{un}) of the unnotched specimen at -170°C may be 690 MPa or more.

[0017] The tensile strength (TS_{un}) of the unnotched specimen at -170°C may be 1.15 times or more the yield strength (YS_{un}) of the unnotched specimen at -170°C .

[0018] An elongation (UE_{un}) at -170°C may be 3% or more.

[0019] The high-performance steel bar according to the embodiment of the present invention includes a surface layer and a center part, and a refined structure of the surface layer may include at least any one of a martensite and a tempered martensite and a refined structure of the center part may include at least two of bainite, ferrite, acicular ferrite, and pearlite.

[0020] According to an aspect of the present invention, a manufacturing method for a high-performance steel bar includes: (S1) a step of preparing a steel material; (S2) a step of hot rolling the steel material by controlling a rolling end temperature to 900 to 1100°C while controlling a reheating temperature to 1050 to 1250°C ; and (S3) a step of cooling the steel material, a steel bar which has undergone the step S3 includes: 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and the balance of iron (Fe) and inevitable impurities and satisfies Formula 1 below.

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times Si(\text{wt}\%) + 81.40 \times Mn(\text{wt}\%) + 94.51 \times Ni(\text{wt}\%) + 202.33 \times Cr(\text{wt}\%) + 5228.70 \times Nb(\text{wt}\%) + 2256.36 \times V(\text{wt}\%) \geq 595.01 \quad [\text{Formula 1}]$$

[0021] In the step S2, a reheating time of the steel material may be 1 to 3 hours.

[0022] In the step S2, a hot rolling thickness reduction rate may be 75% or more.

[0023] In the steel material which has undergone the step S3, the yield strength (YS_{un}) of the unnotched specimen at -170°C may be 600 MPa or more.

[0024] In the steel material which has undergone the step S3, the tensile strength (TS_{un}) of the unnotched specimen at -170°C may be 1.15 times or more the yield strength (YS_{un}) of the unnotched specimen at -170°C .

[0025] In the steel material which has undergone the step S3, the tensile strength (TS_n) of the notch specimen at -170°C may be equal to or more than the yield strength (YS_{un}) of the unnotched specimen at -170°C .

[ADVANTAGEOUS EFFECTS]

[0026] According to one embodiment of the present invention, a high-performance steel bar which is capable of ensuring a yield strength and notch sensitivity under a low temperature environment and a manufacturing method for a steel bar may be implemented.

[0027] The effects of the present invention are not limited to the aforementioned effects, and other effects, which are not mentioned above, will be apparently understood by a person skilled in the art from the recitations of the claims.

[DESCRIPTION OF DRAWINGS]

[0028]

FIG. 1 is a flowchart illustrating a manufacturing method for a high-performance steel bar according to one embodiment of the present invention.

FIG. 2 is a view illustrating a result obtained by observing a surface layer and a center part of a high-performance steel

bar with an optical microscope according to one embodiment of the present invention.

FIG. 3 is a view illustrating an optical microscope observation result of Comparative Example 1 and Example 1 represented in Table 3.

[BEST MODE]

[0029] Hereinafter, the present invention will be described more fully with reference to the accompanying drawings, in which embodiments of the invention are shown. However, the present invention is not restricted or limited by the following embodiments.

[0030] When a component (or an area, a layer, or a portion) is described as being "placed on", "connected to" or "coupled to" another component, it should be understood that it may be directly placed on/connected to/coupled to the other component, but there may be another component therebetween.

[0031] It should be understood that a term "include" or "have" indicates that a feature, a number, a step, an operation, a component, a part or a combination thereof described in the specification is present, but does not exclude a possibility of presence or addition of one or more other features, numbers, steps, operations, components, parts or combinations thereof, in advance.

[0032] In order to clearly describe the present invention, detailed descriptions of parts which are unrelated to the description or well-known related technologies which may unnecessarily obscure the gist of the present invention will be omitted. Further, when reference numerals are denoted to components of each drawing in the present specification, throughout the specification, the same or like components are denoted by the same or like reference numerals.

[0033] Further, terms or words used in the specification and the claims should not be restrictively analyzed as a general or dictionary meaning and should be analyzed as a meaning and a concept which conform to the technical spirit of the present invention based on a principle that the inventor can appropriately define a concept of a term in order to describe his/her own invention by the most method.

[0034] Unless otherwise specified, the notation "A ~ B" with respect to numerical values A and B refers to A or more and B or less. In this notation, when a unit is attached only to the numerical value B, the corresponding unit is also applied to the numerical value A.

[0035] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

High-performance steel bar

[0036] A high-performance steel bar according to one embodiment of the present invention is manufactured by a steel material including 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and the balance of iron (Fe) and inevitable impurities and a steel bar which is a finished product may include the same alloying constituent.

[0037] Hereinafter, a role and a content of each alloying element included in the high-performance steel bar according to one embodiment of the present invention will be described in detail.

Carbon (C)

[0038] Carbon (C) is an element which is the most effective and important to increase the strength of steel.

[0039] Carbon is dissolved in austenite to form a martensitic structure during quenching. Further, the larger the content of carbon, the better the hardness.

[0040] If the content of carbon is insufficient, the above-described effect is insufficient, which makes it difficult to ensure sufficient strength. In contrast, if the content of carbon is excessive, deformation during the quenching and degradation of the elongation rate and low-temperature toughness of the steel material may be caused.

[0041] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.04 to 0.09 wt% of carbon.

Silicon (Si)

[0042] Silicon (Si) is added as a deoxidizer to remove oxygen in the steel during the steel-making process, along with aluminum, and induces the formation of ferrite as a ferrite stabilizing element having a solid solution enhancement effect, thereby improving hardenability and softening resistance of the steel.

[0043] If the content of silicon is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of

silicon is excessive, the toughness may be degraded and plastic processability may be impaired.

[0044] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.6 wt% or less of silicon (Si).

Manganese (Mn)

[0045] Manganese (Mn) is a solid solution enhancement element to not only contribute to strength ensuring and but also improve the hardenability of the steel. Further, as the content of manganese is increased, pearlite is refined and ferrite is strengthened by solid solution to improve the yield strength.

[0046] If the content of manganese is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of manganese is excessive, the austenite structure remains to degrade the strength and the toughness.

[0047] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 1.45 to 2.5 wt% of manganese (Mn).

Nickel (Ni)

[0048] Nickel is an important and general alloying element for low-temperature toughness. Nickel (Ni) refines the structure of steel and is well dissolved in austenite and ferrite to be used for strengthening solid solution.

[0049] If the content of nickel is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of nickel is excessive, a manufacturing cost of steel may be increased and weldability and toughness may be degraded.

[0050] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.2 to 2.0 wt% of nickel (Ni).

Chrome (Cr)

[0051] Chrome (Cr) is a ferrite stabilizing element. If chrome is added to C-Mn steel, diffusion of carbon is delayed due to the solute drag effect, which affects grain refinement. Further, chromium may improve the hardenability of steel and may enhance its quenchability. However, if the content of chromium is excessive, coarse carbide is formed at the particle boundary to degrade room-temperature and low-temperature ductility of steel.

[0052] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.7 wt% or less of chrome (Cr).

Niobium (Nb)

[0053] Niobium (Nb) reacts with carbon or nitrogen in the steel to form precipitate (for example, NbC or Nb(C,N)). If niobium is added, grain growth may be suppressed and grain may be refined due to the peening effect of the precipitate. Further, the strength of a base material and a soldered portion may be improved.

[0054] If the content of niobium is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of niobium is excessive, the precipitate is coarsely formed to reduce the impact property of the steel.

[0055] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.001 to 0.07 wt% of niobium (Nb).

Vanadium (V)

[0056] A carbide formability of vanadium (V) is stronger than chrome (Cr) and refines the structure of steel, which causes the precipitation strengthening when precipitate is formed to help the improvement of the strength. Further, if vanadium is added, the toughness may be improved.

[0057] If the content of vanadium is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of vanadium is excessive, a manufacturing cost of steel may be increased and oxide (for example, V_2O_5) may be evaporated at a high temperature.

[0058] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.03 to 0.09 wt% of vanadium (V).

Phosphorus (P)

[0059] Phosphorus is an element which partially contributes to improvement of strength. If phosphorus is excessively included, the ductility of steel is deteriorated and deviation of a final material is caused by billet center segregation. If a content of phosphorus exceeds 0.02 wt%, center segregation and refined segregation are formed to deteriorate the

ductility of steel and lower the impact value by precipitation behavior.

[0060] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.02 wt% or less of phosphorus (P).

Sulfur (S)

[0061] Sulfur (S) is coupled to manganese, zinc, titanium, or molybdenum to improve the machinability of steel and is coupled to manganese to form the refined precipitate (for example, MnS) to improve the processability. However, if an amount of manganese in the steel is not sufficient, manganese is coupled to iron to form sulfide (for example, FeS) to cause cracks during hot and cold processing. If the content of sulfur exceeds 0.02 wt%, the ductility of steel is deteriorated and toughness and the weldability may be degraded.

[0062] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.02 wt% or less of sulfur (S).

Copper (Cu)

[0063] Approximately 0.1 to 0.3 wt% of copper (Cu) is generally contained in the steel. Copper is dissolved in ferrite up to 0.35 wt% and shows a solid-solution strengthening effect, to improve the strength and the hardness. Further, the corrosion resistance may be increased in the atmosphere or seawater. However, if the content of copper is excessive, the elongation is degraded and specifically, if the content exceeds 0.5 wt%, it may cause the hot brittleness.

[0064] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.5 wt% or less of copper (Cu).

Molybdenum (Mo)

[0065] Only 0.1 to 0.3 wt% of molybdenum (Mo) is added to improve the hardenability up to 10 times more than nickel (Ni) and suppress the temper brittleness, thereby assigning temper brittleness resistance. Molybdenum also forms carbide to be highly effective as an alloying element of high-grade cutting tools and increases the grain coarsening temperature. In order to improve the hardenability, molybdenum may be more effective when it is used together with chrome, rather than being solely used.

[0066] If the content of molybdenum is insufficient, the above-mentioned effect may be insignificant. In contrast, if the content of molybdenum is excessive, a manufacturing cost of steel is increased and weldability may be degraded.

[0067] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.002 to 0.05 wt% of molybdenum (Mo).

Aluminum (Al)

[0068] Aluminum (Al) is added to the steel making process as a deoxidizer to remove oxygen from the steel. Further, aluminum may contribute to the grain refinement by forming precipitate (for example, AlN).

[0069] If the content of aluminum is insufficient, the deoxidation effect may be insignificant. In contrast, if the content of aluminum is excessive, ductility and toughness may be degraded.

[0070] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.001 to 0.07 wt% of aluminum (Al).

Nitrogen (N)

[0071] Nitrogen (N) has a significant effect on the mechanical property of steel even with an extremely small amount and the larger the content of nitrogen, the larger the tensile strength and the yield strength, but the lower the elongation. Specifically, reduction of the impact value and the increase of shift temperature are significant.

[0072] If nitrogen is added, the austenite grain is refined to manufacture fine grain steel and form nitride with titanium, zirconium, vanadium, or niobium, thereby refining the grain. However, if the content of nitrogen is excessive, high-temperature toughness is degraded and grain boundary embrittlement may occur at the austenite grain boundary in accordance with precipitation of nitride.

[0073] Accordingly, the high-performance steel bar according to the embodiment of the present invention may include 0.01 wt% or less of nitrogen (Ni).

[0074] A balance other than the above-described components of steel may include Fe and inevitable impurities. The inevitable impurities are impurities mixed during a steelmaking step and a manufacturing process of a steel bar and are widely known in the art so that a detailed description thereof will be omitted.

[0075] In the embodiment of the present invention, addition of an element other than the above-described alloying constituents is not excluded, but various elements may be included without departing from the technical spirit of the present invention. When an additional element is further included, Fe which is the balance may be replaced.

[0076] Further, the high-performance steel bar according to the embodiment of the present invention may satisfy the following Formula 1.

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times \text{Si}(\text{wt}\%) + 81.40 \times \text{Mn}(\text{wt}\%) + 94.51 \times \text{Ni}(\text{wt}\%) + 202.33 \times \text{Cr}(\text{wt}\%) + 5228.70 \times \text{Nb}(\text{wt}\%) + 2256.36 \times \text{V}(\text{wt}\%) \geq 595.01 \quad [\text{Formula 1}]$$

[0077] In Formula 1, each element indicates a content (wt%) of elements included in the steel bar. For example, if a content of carbon (C) in a steel bar is 0.05 wt%, a C (wt%) value of Formula 1 is 0.05.

[0078] If Formula 1 is satisfied, the high-performance steel bar according to the embodiment of the present invention may have a low-temperature yield strength of 600 MPa or more. Here, the low-temperature yield strength (YS_{un}) refers to a yield strength measured at an unnotched specimen of -170°C .

[0079] Further, the high-performance steel bar according to the embodiment of the present invention may satisfy the following Formula 2.

$$12.45 \times C(\text{wt}\%) + 1145.44 \times \text{Si}(\text{wt}\%) + 238.09 \times \text{Mn}(\text{wt}\%) + 140.14 \times \text{Ni}(\text{wt}\%) + 280.55 \times \text{Cr}(\text{wt}\%) + 4367.63 \times \text{Nb}(\text{wt}\%) + 1749.46 \times \text{V}(\text{wt}\%) \geq 722.32 \quad [\text{Formula 2}]$$

[0080] In Formula 2, each element indicates a content (wt%) of elements included in the steel bar. For example, if a content of carbon (C) in a steel bar is 0.05 wt%, a C (wt%) value of Formula 2 is 0.05.

[0081] If Formula 2 is satisfied, the high-performance steel bar according to the embodiment of the present invention may have a low-temperature unnotched tensile strength (TS_{un}) of 690 MPa or more. Here, the low-temperature unnotched tensile strength (TS_{un}) refers to a tensile strength measured at an unnotched specimen of -170°C .

[0082] If the low-temperature unnotched tensile strength (TS_{un}) is 690 MPa or more, it is possible to suppress or prevent the fracture from being generated in the steel bar even though an external force is applied under the low-temperature (-170°C) environment due to the low-temperature brittleness. To be more desirable, the low-temperature unnotched tensile strength (TS_{un}) may be 1.15 times or more the low-temperature yield strength (YS_{un}).

[0083] Further, the high-performance steel bar according to the embodiment of the present invention may have a low-temperature notch tensile strength (TS_n) of 600 MPa or more. Here, the low-temperature notch tensile strength (TS_n) refers to a tensile strength measured at a notched specimen of -170°C .

[0084] If the low-temperature notch tensile strength (TS_n) is 600 MPa or more, the notch sensitivity ratio (NSR) may be improved. Here, the low-temperature notch sensitivity (NSR) is a ratio (TS_n/YS_{un}) of a tensile strength (TS_n) and the yield strength (YS_{un}) measured from the notched specimen at -170°C .

[0085] As the low-temperature notch sensitivity ratio (NSR) is improved, even though the steel bar is notched, the fatigue failure is suppressed or prevented from being generated due to the notch under the low-temperature (-170°C) environment. More desirably, the low-temperature notch sensitivity ratio (NSR) may be 1.0 or larger.

[0086] The high-performance steel bar according to the embodiment of the present invention may have 3% or larger of low-temperature elongation (UE_{un}). Here, the low-temperature elongation (UE_{un}) refers to an elongation measured at an unnotched specimen of -170°C .

[0087] If the low-temperature elongation is 3% or more, it is possible to suppress or prevent the fracture from being generated in the steel bar even though an external force is applied under the low-temperature (-170°C) environment due to the low-temperature brittleness.

[0088] Hereinafter, a manufacturing method for a high-performance steel bar according to one embodiment of the present invention will be described in detail.

Manufacturing method for high-performance steel bar

[0089] Hereinafter, a manufacturing method for a high-performance steel bar according to one embodiment of the present invention will be described with reference to FIG. 1.

[0090] FIG. 1 is a flowchart illustrating a manufacturing method for a high-performance steel bar according to one embodiment of the present invention.

[0091] The manufacturing method for a high-performance steel bar according to one embodiment of the present invention includes a first step S1 of preparing a steel material which is a half-finished product, a second step S2 of hot rolling the steel material prepared in the first step S1, thereby forming a hot-rolled material, and a third step S3 of cooling the hot-rolled material.

[0092] Hereinafter, individual steps of the manufacturing method for a high-performance steel bar according to one embodiment of the present invention will be described in detail.

[0093] The first step S1 of preparing a steel material which is a half-finished product is a step of preparing a steel material having the above-described alloying composition range to manufacture a high-performance steel bar which is a finished product. To be more specific, the alloying constituent is designed in the above-described alloying composition range to manufacture a half-finished product. The half-finished product may be a billet or a bloom, but is not limited thereto. Further, the half-finished product may be prepared by a known process in the art, such as a steelmaking process or a continuous casting process.

[0094] In the manufacturing method for a high-performance steel bar according to one embodiment of the present invention, in the second step S2, the steel material which has undergone the first step S1 is hot-rolled to form a hot-rolled material. The second step S2 may include a reheating step and a hot rolling step.

[0095] First, the reheating step is performed prior to the hot rolling step to reheat the steel material for the subsequent process. To be more specific, in the reheating step, the steel material is charged into a heating furnace to uniformly heat the steel material to easily perform plastic deformation.

[0096] The steel material may be reheated at a temperature condition of 1050 to 1250°C. If the reheating temperature is below 1050°C, a deformation resistance is increased during the hot rolling and the rolling load is increased, thereby deteriorating the rollability. In contrast, if the reheating temperature exceeds 1250°C, the austenite grain is coarsened or decarburization is caused to deteriorate the strength. In addition, due to the increase in the heating cost and time, the manufacturing cost may be increased and the productivity may be lowered.

[0097] Further, the steel material may be reheated for 1 to 3 hours. If the reheating time is shorter than one hour, the rolling load may be increased. In contrast, if the reheating time exceeds three hours, the grain may be excessively coarsened.

[0098] Accordingly, in the present invention, the steel material may be reheated for one to three hours at a temperature of 1000 to 1200°C.

[0099] Next, the hot rolling step may be performed. The hot rolling step may include rough rolling and finishing rolling processes. Here, during the rough rolling process, the steel material is created as a rolled material with appropriate shape, thickness, and width and during the finishing rolling process, the steel material is adjusted to have a predetermined size and is rolled to have a satisfactory surface and shape at a correct finishing temperature.

[0100] At this time, the finishing rolling temperature may be 900 to 1100°C. If the finishing rolling temperature is lower than 900°C, the rolling load is increased, which lowers the productivity and reduces the heat-treatment effect. In contrast, if the finishing rolling temperature exceeds 1100°C, the pearlite structure is coarsely formed to sharply deteriorate the strength. Accordingly, the finishing rolling temperature may be desirably 900 to 1100°C and more desirably, 950 to 1050°C.

[0101] The hot rolling step may be performed at 75% or higher of thickness reduction rate and more desirably, may be performed at 78% or higher of thickness reduction rate.

[0102] Next, the manufacturing method for a high-performance steel bar according to one embodiment of the present invention may perform the third step S3 of cooling the hot-rolled material which has undergone the second step S2. In the third step S3, the hot-rolled material may be cooled by a temp-core process.

[0103] Specifically, in the third step S3, the hot-rolled material may be quenched in the temperature range of 500 to 610°C at a cooling rate of 100 to 400°C/sec. The above-described temperature range refers to a surface temperature of the hot-rolled material.

[0104] After the quenching, the surface of the hot-rolled material may be recuperated to the temperature range of 535 to 630°C by the residual heat therein and then may be air-cooled to the room temperature.

[0105] The high-performance steel bar manufactured by the manufacturing method for a high-performance steel bar according to the embodiment of the present invention may satisfy all the low-temperature yield strength (YS_{un}), the low-temperature unnotched tensile strength (TS_{un}), the low-temperature notch tensile strength (TS_n), and the low-temperature elongation (UE_{un}) values.

[0106] Further, the high-performance steel bar manufactured by the manufacturing method for a high-performance steel bar according to the embodiment of the present invention may satisfy the ratio (TS_{un}/YS_{un}) of the low-temperature tensile strength and the low-temperature yield strength and the low-temperature notch sensitivity (NSR) values.

[0107] The high-performance steel bar manufactured by the manufacturing method for a high-performance steel bar according to the embodiment of the present invention may include a surface layer including at least any one refined structure of a martensite and a tempered martensite and a center part including at least two refined structures of bainite, ferrite, acicular ferrite, and pearlite. This will be described in detail further with reference to FIG. 2.

[0108] FIG. 2 is a view illustrating a result obtained by observing a surface layer and a center part of a high-performance steel bar with an optical microscope according to one embodiment of the present invention. (a) of FIG. 2 is a result obtained by observing a center part of the high-performance steel bar according to the present invention and (b) of FIG. 2 is a result obtained by observing a surface layer of the high-performance steel bar according to the present invention.

[0109] Further referring to FIG. 2, the center part of the high-performance steel bar according to the embodiment of the

present invention may be configured by a composite structure including two or more refined structures of bainite, ferrite, acicular ferrite, and pearlite. In FIG. 2, it is confirmed that the center part (a) of the high-performance steel bar has a refined structure configured by bainite, pearlite, and acicular ferrite.

[0110] Further, the surface layer of the high-performance steel bar according to the embodiment of the present invention may be configured by at least any one refined structure of a martensite and a tempered martensite. In FIG. 2, it is confirmed that the surface layer (b) of the high-performance steel bar has a refined structure configured by a martensite and a tempered martensite.

[0111] As the steel bar includes the center part and the surface layer and is configured by the above-described refined structure so that the present invention may provide a high-performance steel bar which is capable of ensuring the yield strength and the notch sensitivity under the low-temperature environment and a manufacturing method for a high-performance steel bar.

Comparative Examples and Examples

[0112] Hereinafter, desirable Examples and Comparative Examples are proposed for better understanding of the present invention. However, the following Examples and Comparative Examples are provided to help the understanding of the present invention, but the present invention is not limited by the following Examples.

[0113] Table 1 represents alloying element compositions of Comparative Examples and Examples and Table 2 represents whether to satisfy Formulas 1 and 2 and low-temperature physical property values of Comparative Examples and Examples. Table 3 is a measurement result of a grain size and a refined structure fraction of Comparative Example 1 and Example 1.

[0114] FIG. 3 is a view illustrating an optical microscope observation result of Comparative Example 1 and Example 1. (c) of FIG. 3 is an observation result of a refined structure of a center part of Comparative Example 1 and (d) of FIG. 3 is an observation result of a refined structure of a center part of Example 1.

[0115] Comparative Examples and Examples were manufactured by a half-finished product having an alloying composition represented in the following Table 1 and undergone a reheating step at a temperature of 1200°C for two hours. Next, the hot rolling was performed at a rolling end temperature of 1000°C with 78% of thickness reduction rate to manufacture a specimen with a diameter of 20 mm.

[0116] Further, Comparative Examples and Examples were cooled to 550°C at a cooling rate of 300°C/sec, reheated to 600°C with internal residual heat, and then air-cooled.

[0117] Further, the manufacturing process of Comparative Examples and Examples of the present invention was controlled by the same condition within the range described in the above-described manufacturing method for a high-performance steel bar according to the embodiment of the present invention with the control variable, other than the above-described conditions.

[0118] In the following Table 3, the grain size and the refined structure fraction of Comparative Example 1 and Experimental Example 1 were analyzed by the optical microscope.

[0119] Further, the low-temperature physical property of Comparative Example and Example 1 was measured under the environment of -170°C.

[0120] In the following Table 1, a composition unit of the alloying element is wt%, and in the following Table 2, units of the low-temperature yield strength (YS_{un}), the low-temperature unnotched tensile strength (TS_{un}), and the low-temperature notch tensile strength (TS_n) are MPa and a unit of the low-temperature elongation (UE_{un}) is %.

[Table 1]

Classification	Chemical component [wt.%]												
	C	Si	Mn	P	S	Cr	Cu	Ni	Mo	Al	Nb	v	N
Comp. Ex. 1	0.06	0.14	1.44	0.001	0.002	0.20	0.15	1.44	0.003	0.005	0.003	0.003	0.01
Comp. Ex. 2	0.06	0.15	1.56	0.001	0.002	0.98	0.16	0.55	0.003	0.005	0.04	0.003	0.01
Comp. Ex. 3	0.06	0.15	1.59	0.001	0.002	0.20	0.16	0.53	0.003	0.005	0.003	0.100	0.01
Ex. 1	0.06	0.15	1.88	0.001	0.001	0.20	0.14	1.54	0.003	0.003	0.003	0.003	0.01
Ex. 2	0.06	0.17	1.63	0.001	0.002	0.20	0.15	0.52	0.003	0.005	0.04	0.003	0.01
Ex. 3	0.06	0.14	1.85	0.001	0.001	0.20	0.14	1.49	0.003	0.003	0.003	0.079	0.01
Ex. 4	0.06	0.16	2.37	0.001	0.002	0.21	0.16	0.55	0.003	0.005	0.003	0.003	0.01

[Table 2]

Classification	Formula 1		Formula 2		YS _{un} (MPa)	TS _{un} (MPa)	TS _{un} /Y S _{un}	TS _n (MPa)	NS R	UE _{un} (%)
	Left side value	Whether to satisfy	Left side value	Whether to satisfy						
Comp. Ex. 1	578.38	Not satis- fied	780.19	Satisfied	586.2	711.5	1.21	578.50	0.99	19.5
Comp. Ex. 2	866.89	Satisfied	1075.93	Satisfied	653	825.9	1.26	617.80	0.95	19.5
Comp. Ex. 3	735.03	Satisfied	869.54	Satisfied	713.1	782.5	1.10	705.12	0.99	15.9
Ex. 1	635.23	Satisfied	910.42	Satisfied	655.3	817	1.25	658.12	1.00	8.6
Ex. 2	735.09	Satisfied	892.47	Satisfied	697.9	808.1	1.16	785.85	1.13	17.2
Ex. 3	787.97	Satisfied	1017.77	Satisfied	748	904.6	1.21	751.20	1.00	7.3
Ex. 4	595.14	Satisfied	902.61	Satisfied	606.4	861.2	1.42	668.14	1.10	19.7

[Table 3]

Classification	Grain size (average)	Grain size (standard deviation)	Ferrite fraction
Comp. Ex. 1	11.8 μm	9.7 μm	89.6%
Ex. 1	9.6 μm	6.5 μm	83.5%

[0121] Referring to Tables 1 and 2, in Comparative Example 1, another alloying composition range satisfies all the ranges according to one embodiment of the present invention, a content of manganese (Mn) is 1.44 wt% and a left side value of Formula 1 is 578.38.

[0122] It is confirmed that in Comparative Example 1, a content of manganese (Mn) does not satisfy the above-described range according to one embodiment of the present invention, that is, 1.45 to 2.5 wt%, and the left side value of Formula 1 does not satisfy the above-described range according to one embodiment of the present invention, that is, 595.01 or higher, so that the low-temperature yield strength (YS_{un}) value and the low-temperature notch sensitivity (NSR) do not satisfy the target ranges of the present invention, that is, 600 MPa or higher and 1.0 or higher.

[0123] In Comparative Example 2, Formula 1 and another alloying composition range satisfy all the ranges according to one embodiment of the present invention and a content of chrome (Cr) is 0.98 wt%.

[0124] It is confirmed that in Comparative Example 2, a content of chrome (Cr) does not satisfy the above-described range according to one embodiment of the present invention, that is, 0.7 wt% or less so that the low-temperature notch sensitivity (NSR) is 0.95, which does not satisfy the target range of the present invention, that is, 1.0 or higher.

[0125] In Comparative Example 3, Formula 1 and another alloying composition range satisfy all the ranges according to one embodiment of the present invention and a content of vanadium (V) is 0.1 wt%.

[0126] It is confirmed that in Comparative Example 3, a content of vanadium (V) does not satisfy the above-described range according to one embodiment of the present invention, that is, 0.03 to 0.09 wt% so that the low-temperature unnotched tensile strength (TS_{un}) does not satisfy 1.15 times or more the low-temperature yield strength (YS_{un}) and the low-temperature notch sensitivity (NSR) does not satisfy the target range of the present invention, that is, 1.0 or higher.

[0127] In contrast, it is confirmed that in Examples 1 to 4 according to the embodiment of the present invention, the alloying composition range satisfies all the ranges of the embodiment of the present invention and also satisfies Formula 1. By doing this, it is confirmed that the values of the low-temperature yield strength (YS_{un}), the low-temperature unnotched tensile strength (TS_{un}), the low-temperature notch tensile strength (TS_n), and the low-temperature elongation (UE_{un}) values satisfy all the target ranges of the present invention.

[0128] Further, referring to Table 3 and FIG. 3, it is confirmed that in Comparative Example 1, an average grain size is 11.8 μm, a standard deviation is 9.7 μm, and a ferrite area fraction is 89.6%. In contrast, it is confirmed that in Example 1, an average grain size is 9.6 μm, a standard deviation is 6.5 μm, and a ferrite area fraction is 83.5%.

[0129] By doing this, it is confirmed that in Example 1, the grain is finer than Comparative Example 1 and bainite is formed instead of ferrite so that the low-temperature yield strength and the notch sensitivity are improved.

[0130] As described above, the embodiments of the present invention have been described and it is obvious to those skilled in the art that the present invention can be embodied in other specific forms without departing from the spirit or scope of the present invention. Therefore, it should be understood that the embodiment is not restrictive, but is illustrative and thus the present invention is not limited to the above-described embodiment but may be modified within the scope of the

accompanying claims and the equivalent range.

Claims

1. A high-performance steel bar comprising:

0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and a balance of iron (Fe) and inevitable impurities and satisfies Formula 1 below, wherein a yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more:

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times Si(\text{wt}\%) + 81.40 \times Mn(\text{wt}\%) + 94.51 \times Ni(\text{wt}\%) + 202.33 \times Cr(\text{wt}\%) + 5228.70 \times Nb(\text{wt}\%) + 2256.36 \times V(\text{wt}\%) \geq 595.01. \quad [\text{Formula 1}]$$

2. The high-performance steel bar of claim 1, wherein a tensile strength (TS_{un}) of the unnotched specimen at -170°C is 690 MPa or more.

3. The high-performance steel bar of claim 2, wherein the tensile strength (TS_{un}) of the unnotched specimen at -170°C is 1.15 times or more the yield strength (YS_{un}) of the unnotched specimen at -170°C.

4. The high-performance steel bar of claim 1, wherein a tensile strength (TS_n) of a notch specimen at -170°C is 600 MPa or more.

5. The high-performance steel bar of claim 4, wherein the tensile strength (TS_n) of the notch specimen at -170°C is equal to or more than the yield strength (YS_{un}) of the unnotched specimen at -170°C.

6. A high-performance steel bar comprising:

0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chrome (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and a balance of iron (Fe) and inevitable impurities, wherein a yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more and a tensile strength (TS_n) of a notch specimen at -170°C is 600 MPa or more.

7. The high-performance steel bar of claim 6, wherein the tensile strength (TS_n) of the notch specimen at -170°C is equal to or more than the yield strength (YS_{un}) of the unnotched specimen at -170°C.

8. The high-performance steel bar of claim 6, wherein Formula 1 below is satisfied:

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times Si(\text{wt}\%) + 81.40 \times Mn(\text{wt}\%) + 94.51 \times Ni(\text{wt}\%) + 202.33 \times Cr(\text{wt}\%) + 5228.70 \times Nb(\text{wt}\%) + 2256.36 \times V(\text{wt}\%) \geq 595.01. \quad [\text{Formula 1}]$$

9. The high-performance steel bar of claim 6, wherein the tensile strength (TS_{un}) of the unnotched specimen at -170°C is 690 MPa or more.

10. The high-performance steel bar of claim 9, wherein the tensile strength (TS_{un}) of the unnotched specimen at -170°C is 1.15 times or more the yield strength (YS_{un}) of the unnotched specimen at -170°C.

11. The high-performance steel bar of claim 6, wherein an elongation (UE_{un}) at -170°C is 3% or more.

12. The high-performance steel bar of claim 6, comprising:

a surface layer and a center part,
wherein a refined structure of the surface layer includes at least any one of a martensite and a tempered martensite and a refined structure of the center part includes at least two of bainite, ferrite, acicular ferrite, and pearlite.

13. A manufacturing method for a high-performance steel bar, comprising:

(S1) a step of preparing a steel material;
(S2) a step of hot rolling the steel material by controlling a rolling end temperature to 900 to 1100°C while controlling a reheating temperature to 1050 to 1250°C; and
(S3) a step of cooling the steel material,
wherein a steel bar which has undergone the step S3 includes: 0.04 to 0.09 wt% of carbon (C), 0.6 wt% or less (excluding 0) of silicon (Si), 1.45 to 2.5 wt% of manganese (Mn), 0.2 to 2.0 wt% of nickel (Ni), 0.7 wt% or less (excluding 0) of chromium (Cr), 0.001 to 0.07 wt% of niobium (Nb), 0.003 to 0.09 wt% of vanadium (V), 0.02 wt% or less (excluding 0) of phosphorus (P), 0.02 wt% or less (excluding 0) of sulfur (S), 0.5 wt% or less (excluding 0) of copper (Cu), 0.002 to 0.05 wt% of molybdenum (Mo), 0.001 to 0.07 wt% of aluminum (Al), 0.01 wt% or less (excluding 0) of nitrogen (N) and a balance of iron (Fe) and inevitable impurities and satisfies Formula 1 below:

$$1668.26 \times C(\text{wt}\%) + 1157.54 \times \text{Si}(\text{wt}\%) + 81.40 \times \text{Mn}(\text{wt}\%) + 94.51 \times \text{Ni}(\text{wt}\%) + 202.33 \times \text{Cr}(\text{wt}\%) + 5228.70 \times \text{Nb}(\text{wt}\%) + 2256.36 \times \text{V}(\text{wt}\%) \geq 595.01. \quad [\text{Formula 1}]$$

14. The manufacturing method for a high-performance steel bar of claim 13, wherein in the step S2, a reheating time of the steel material is 1 to 3 hours.

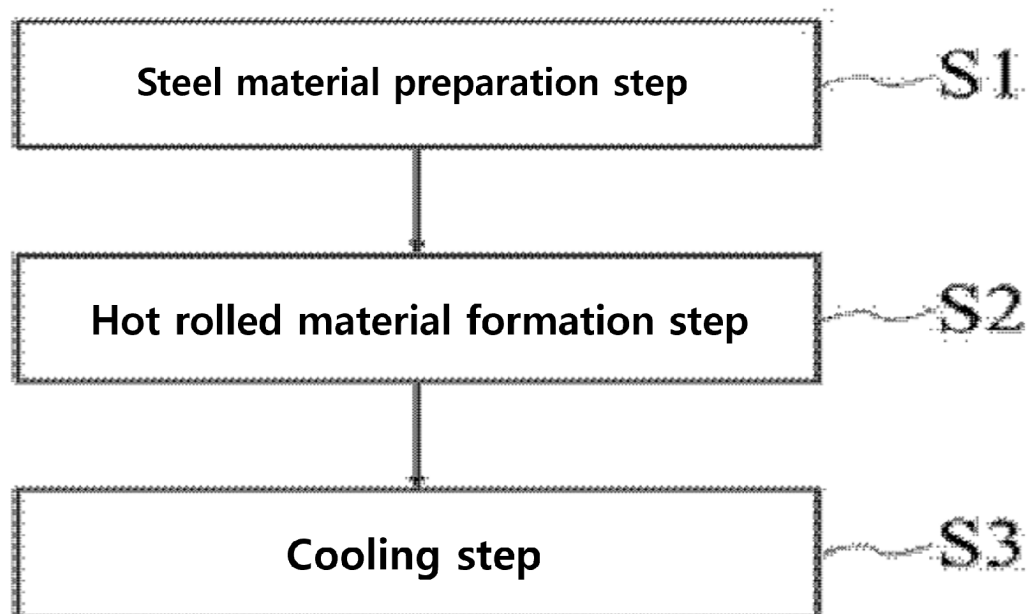
15. The manufacturing method for a high-performance steel bar of claim 13, wherein in the step S2, a hot rolling thickness reduction rate is 75% or more.

16. The manufacturing method for a high-performance steel bar of claim 13, wherein in the steel material which has undergone the step S3, a yield strength (YS_{un}) of an unnotched specimen at -170°C is 600 MPa or more.

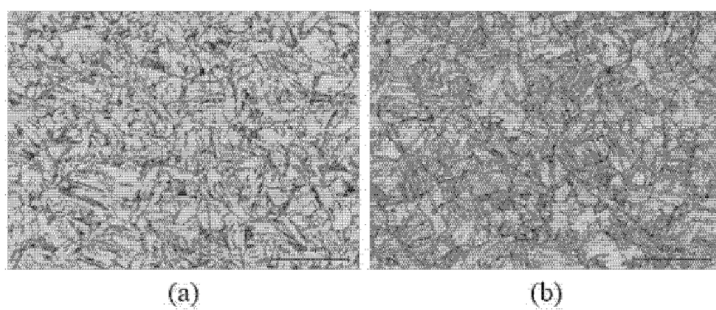
17. The manufacturing method for a high-performance steel bar of claim 16, wherein in the steel material which has undergone the step S3, a tensile strength (TS_{un}) of the unnotched specimen at -170°C is 1.15 times or more the yield strength (YS_{un}) of the unnotched specimen at -170°C.

18. The manufacturing method for a high-performance steel bar of claim 16, wherein in the steel material which has undergone the step S3, a tensile strength (TS_n) of a notch specimen at -170°C is equal to or more than the yield strength (YS_{un}) of the unnotched specimen at -170°C.

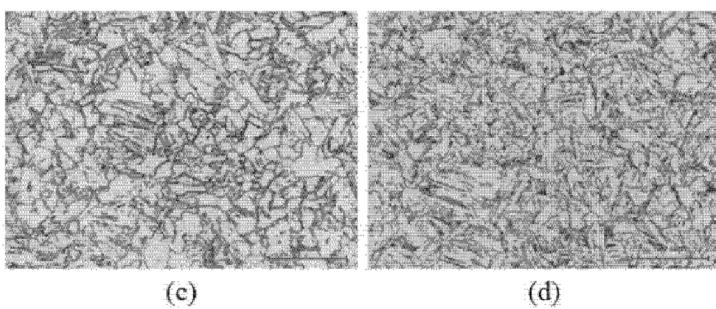
[Fig. 1]



[Fig. 2]



[Fig. 3]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/012745

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; **C22C 38/48**(2006.01)i; **C22C 38/46**(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/44**(2006.01)i;
C22C 38/00(2006.01)i; **C21D 8/06**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/58(2006.01); C21D 8/00(2006.01); C21D 8/02(2006.01); C21D 8/06(2006.01); C22C 38/00(2006.01)

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 극저온(low temperature), 봉강(bar, rod), 철근(rebar, reinforced), 열간성형(hot forming), 마르텐사이트(martensite)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001-234285 A (NIPPON STEEL CORP.) 28 August 2001 (2001-08-28) See paragraphs [0025] and [0030]-[0031] and claims 1-3 and 6.	1-11,13,15-18
Y		12,14
Y	KR 10-2012-0000766 A (HYUNDAI STEEL COMPANY) 04 January 2012 (2012-01-04) See paragraph [0074] and claim 1.	12,14
A	KR 10-2023-0062073 A (HYUNDAI STEEL COMPANY) 09 May 2023 (2023-05-09) See claim 1.	1-18
A	KR 10-2012-0000799 A (HYUNDAI STEEL COMPANY) 04 January 2012 (2012-01-04) See claims 1-2.	1-18
A	JP 10-280088 A (SUMITOMO METAL IND. LTD.) 20 October 1998 (1998-10-20) See claim 1.	1-18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“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 03 December 2024	Date of mailing of the international search report 03 December 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/012745

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Form PCT/ISA/210 (patent family annex) (July 2022)