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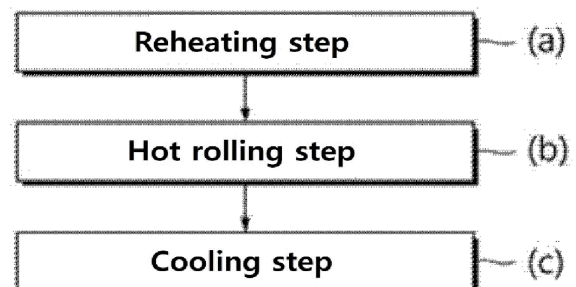
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(54) **HIGH-PERFORMANCE STEEL BAR AND MANUFACTURING METHOD THEREFOR**

(57) A high-performance steel bar, according to one embodiment of the present disclosure includes: 0.08-0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si); 0.6-3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002-0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01-3.40 wt% of nickel (Ni), 0.002-0.10 wt% of molybdenum (Mo), 0.005-0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001-0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and the balance of iron (Fe) and inevitable impurities, in which the room-temperature yield strength (YS) satisfies at least 500 MPa.

【Fig. 1】



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Description**[Technical Field]**

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

[Background Art]

[0002] Deformed steel bars or reinforcing bars are elongated steel materials used for concrete reinforcement, and have been widely used in construction and civil engineering sites due to an advantage of reducing the crack width when concrete cracks occur by compensating for concrete having large adhesion to concrete and being vulnerable to tension.

[0003] These deformed steel bars or reinforcing bars are used today as pivotal materials in various civil engineering and construction structures, such as bridges, massive offshore structures, underground structures, and storage facilities.

[0004] Recently, the demand and interest in liquefied natural gas (LNG) have increased globally due to the Russia-Ukraine war, national nuclear phase-out policies, the growing demand for renewable energy sources such as wind and solar power to expand green energy sources, and the increase in mining reserves resulting from advancement in natural gas extraction technology. Specifically, LNG is expected to grow at a high rate of 46.1%, from 2.9 billion TOU of the total energy mix in 2013 to 4.2 billion TOU by 2040.

[0005] Meanwhile, natural gas is transported to an LNG terminal and stored through a refining and liquefaction process. The natural gas is liquefied at -170°C (cryogenic temperature) or lower to become liquefied natural gas (LNG), and an LNG storage tank for storing cryogenic LNG needs to be applied with materials that may withstand cryogenic temperatures.

[0006] The LNG tank is largely composed of an inner shell and an outer shell, each made of 9% Ni steel and reinforced concrete. In the past, the LNG tank was designed as a double containment type with a containment wall built on the outside of the LNG tank, but since the late 1980s, the design has transformed into a fully containment type design with the inner and outer shells tightly contacted with other. Through this, although LNG may leak due to damage to the inner shell, leakage into the ground and air was prevented by the outer shell.

[0007] Therefore, in the case of deformed steel bars used in an LNG storage tank, material properties capable of withstanding -170°C are required to maintain its structure without brittle fracture even during a rapid temperature drop caused by LNG leakage.

[Disclosure]**[Technical Problem]**

[0008] In order to solve the problems in the related art, an object of the present disclosure is to provide a high-performance steel bar having excellent mechanical properties such as toughness and ductility even in a cryogenic environment, and a manufacturing method therefor.

[0009] Another object of the present disclosure is to provide a high-performance steel bar with stable performance in room temperature and cryogenic environments, and a manufacturing method therefor.

[0010] The objects of the present disclosure are not limited to the aforementioned objects, and other objects, which are not mentioned above, will be apparent to those skilled in the art from the following description.

[Technical Solution]

[0011] According to an embodiment of the present disclosure, a high-performance steel bar includes: 0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and the balance of iron (Fe) and inevitable impurities, in which the room-temperature yield strength (YS) satisfies 500 MPa or higher.

[0012] In addition, the high-performance steel bar may further include at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).

[0013] In addition, the average grain size of a ferrite structure may be 5.0 to 13.2 μm .

[0014] In addition, a ductile-brittle transition temperature (DBTT) may be -41°C or lower.

[0015] In addition, a final microstructure may include polygonal ferrite, acicular ferrite, pearlite, and bainite.

[0016] In addition, the elongation at room temperature may be 14% or more.

[0017] According to another embodiment of the present disclosure, a manufacturing method of a high-performance steel bar includes: (a) reheating a steel material including 0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and the balance of iron (Fe) and inevitable impurities; (b) hot rolling the steel material by controlling a rolling start temperature to 950 to 1100°C and a rolling end temperature to 800 to 1000°C; and (c) cooling the steel material.

[0018] In addition, the steel material may further include at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).

[0019] In addition, in step (b), the rolling end temperature may be controlled below a recrystallization stop temperature of the steel material.

[0020] In addition, step (c) may be performed by accelerate control cooling (ACC), which may be cooled at a cooling rate of 30 to 400°C/sec, and cooled to a final cooling temperature of 500 to 700°C.

[0021] In addition, the steel bar that has undergone step (c) may have an average grain size of the ferrite structure of 5.0 to 13.2 μm or less.

[0022] In addition, the steel bar that has undergone step (c) may have a ductile-brittle transition temperature (DBTT) of -41°C or lower.

[0023] The steel bar that has undergone step (c) may have a microstructure including polygonal ferrite, bainite, acicular ferrite, and pearlite.

[Advantageous Effects]

[0024] According to the high-performance steel bar and the manufacturing method therefor according to an embodiment of the present disclosure, it is possible to secure excellent mechanical properties such as room-temperature properties, low-temperature toughness, and cryogenic toughness and ductility.

[0025] The effects of the present disclosure are not limited to the aforementioned effect, and other effects not mentioned above will be clearly understood to those skilled in the art from the description of the appended claims.

[Description of Drawings]

[0026]

FIG. 1 is a flowchart illustrating a process sequence of a manufacturing method of a high-performance steel bar according to an embodiment of the present disclosure.

FIG. 2 shows final microstructure images of Comparative Material and Inventive Material.

[Best Mode]

[0027] In this specification, when a component (or region, layer, part, etc.) is described as being "on", "connected to" or "coupled to" the other component, it means that the component may be directly displaced/connected/coupled on the other component, or a third component may also be displaced therebetween.

[0028] Like reference numerals designate like components. In addition, in the drawings, the thickness, proportion, and dimension of components are exaggerated to effectively explain the technical content.

[0029] "And/or" includes all one or more combinations that associated configurations may be defined.

[0030] Although the terms of first, second, etc. may be used for describing various components, the components should not be limited by these terms. These terms are only used to distinguish one component from another component. For example, without departing from the scope of the present disclosure, a first component may be named as a second component, and similarly, a second component may be named as a first component. A singular expression includes a plural expression unless the context clearly indicates otherwise.

[0031] In addition, terms such as "under", "below", "on", and "above" are used to describe a relationship between components illustrated in the drawings. The terms are relative concepts and are explained based on directions indicated in the drawings.

[0032] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as being generally understood by those skilled in the art to which the present disclosure pertains. In addition,

terms such as those defined in commonly used dictionaries should be interpreted as having meanings consistent with their meanings in the context of the relevant technology, and are explicitly defined herein unless interpreted in an ideal or overly formal sense.

[0033] It should be understood that term "including" or "having" 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 the possibility of presence or addition of one or more other features, numbers, steps, operations, components, parts or combinations thereof, in advance.

[0034] Unless otherwise specified, the expression 'A ~ B' for numerical values A and B means 'A or more and B or less'. In such expression, if a unit is attached only to numerical value B, the corresponding unit is also applied to numerical value A.

[0035] Hereinafter, an embodiment of the present disclosure will be described in more detail with reference to the drawings.

High-performance steel bar

[0036] A high-performance steel bar according to an embodiment of the present disclosure includes 0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and the balance of iron (Fe) and inevitable impurities.

[0037] In the high-performance steel bar according to an embodiment of the present disclosure including the alloy composition described above, the room-temperature yield strength (YS) satisfies 500 MPa or higher.

[0038] The high-performance steel bar according to the present disclosure may secure excellent room-temperature mechanical properties, low-temperature toughness, and toughness and ductility in a cryogenic environment such as -170°C. More specifically, the high-performance steel bar according to the present disclosure may have improved low-temperature toughness together with strength in a cryogenic environment, and exhibit excellent product characteristics by preventing brittle fracture even with a rapid temperature drop when applied to cryogenic structures.

[0039] Accordingly, the high-performance steel bar according to the present disclosure is able to be applied not only to an outer shell of an LNG storage tank but also to civil engineering and construction structures in polar regions, and may be variously used as a safe steel material.

[0040] Meanwhile, the high-performance steel bar according to an embodiment of the present disclosure may further include at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).

[0041] Hereinafter, the roles and contents of each alloy element included in the high-performance steel bar according to an embodiment of the present disclosure will be described in detail.

Carbon (C)

[0042] Carbon (C) is the most effective and important element for increasing the strength of steel, and it dissolves into austenite to form a martensite structure during quenching. An increase in carbon content improves quenching hardness, but causes deformation during quenching or a decrease in elongation and low-temperature toughness of the steel material. The carbon combines with elements such as iron (Fe), chromium (Cr), molybdenum (Mo), and vanadium (V) to form carbides, thereby improving the strength and hardness.

[0043] Taking this into account, the high-performance steel bar according to an embodiment of the present disclosure may include 0.08 to 0.26 wt% of carbon (C), preferably 0.09 to 0.17 wt% of carbon (C).

Silicon (Si)

[0044] Silicon (Si) is a residue from pig iron and a deoxidizer, and dissolves into ferrite as long as it does not form compounds such as SiO₂, and thus does not significantly affect the mechanical properties of steel. In addition, as a strong deoxidizer, up to 4.5 wt% of a silicon is added to improve the strength, but adding 2 wt% or higher thereof may reduce toughness and impair plastic workability, so that there is a limit to the amount to be added. The silicon also has an effect of increasing softening resistance during tempering.

[0045] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.50 wt% or less (excluding 0) of silicon (Si), preferably 0.151 to 0.50 wt% of silicon (Si).

Manganese (Mn)

[0046] Some of manganese (Mn) contained in steel dissolves into steel, while some thereof combines with sulfur contained in the steel to form MnS, a non-metallic inclusion, and the MnS is ductile and thus elongates in a processing direction during plastic working. However, a sulfur (S) component in the steel is reduced due to the formation of MnS, thereby making crystal grains brittle and inhibiting the formation of FeS, which is a low-melting compound. In addition, when added with an austenite stabilizing element in an amount of 1.4 to 2.0 wt%, it is advantageous for the formation of acicular ferrite and bainite.

[0047] In addition, steel added with 1.0 to 1.5% of manganese is called tough steel because it provides the viscosity to the steel.

[0048] In consideration of this, the high-performance steel bar according to an embodiment of the present disclosure may include 0.60 to 3.0 wt% of manganese (Mn) to induce the formation of a microstructure favorable for improving cryogenic toughness and reduction of the content of expensive nickel (Ni), and may include preferably 0.76 to 1.82 wt%, more preferably 1.01 to 1.62 wt%.

Phosphorus (P)

[0049] Phosphorus (P) is not a significant concern if it is uniformly distributed in steel, but it usually forms a harmful compound of Fe₃P. This Fe₃P is extremely brittle and segregated, and thus is not homogenized even after annealing and is elongated during processing such as forging and rolling. In addition, the phosphorus (P) reduces impact resistance, promotes temper brittleness, and improves machinability in free-cutting steel, but generally it is regarded as a harmful element to steel whose content must be controlled.

[0050] In consideration of this, the high-performance steel bar according to an embodiment of the present disclosure may include 0.025 wt% or less (excluding 0) of phosphorus (P).

Sulfur (S)

[0051] Sulfur (S) usually combines with manganese, zinc, titanium, molybdenum, etc., to improve the machinability of steel, and combines with manganese to form MnS inclusions. If the amount of manganese in the steel is insufficient, the sulfur combines with iron to form FeS. The FeS is very brittle and has a low melting point to cause cracks during hot and cold working.

[0052] The sulfur (S) content is controlled to improve elongation and secure low-temperature toughness while avoiding the formation of FeS inclusions.

[0053] To this end, the high-performance steel bar according to an embodiment of the present disclosure may include 0.025 wt% or less (excluding 0) of sulfur (S).

Chromium (Cr)

[0054] Chromium (Cr) is a ferrite stabilizing element, and delays carbon diffusion due to a solute interference effect when added to C-Mn steel, thereby affecting grain size refinement. The chromium (Cr) also serves to improve hardenability. At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.002 to 0.5 wt% of chromium (Cr).

Copper (Cu)

[0055] Copper (Cu) dissolves into ferrite up to 0.35 wt% at room temperature and exhibits a solid solution strengthening effect, so that the strength and hardness are slightly improved, but the elongation is reduced. Steel containing copper has a problem in hot workability, and in particular, if more than 0.5 wt% of copper is contained, the copper causes red-hot brittleness.

[0056] To this end, the high-performance steel bar according to an embodiment of the present disclosure may include 0.5 wt% or less (excluding 0) of copper (Cu).

Nickel (Ni)

[0057] Nickel (Ni) is the most important and common alloying element together with chromium. The nickel (Ni) refines the structure of steel and dissolves well into austenite and ferrite, which is used for matrix strengthening. When coexisting with chromium (Cr) or molybdenum (Mo), the nickel (Ni) exhibits excellent hardenability and facilitates heat treatment of large steel materials. The nickel (Ni) enhances the low-temperature toughness of steel and does not

impair weldability or malleability. However, since the nickel (Ni) is an element with a high alloy unit cost, it is necessary to control its composition content by considering a cost aspect.

[0058] In consideration of this, the high-performance steel bar according to an embodiment of the present disclosure may include 0.01 to 3.4 wt% of nickel (Ni), preferably 0.03 to 0.58 wt% of nickel (Ni).

Molybdenum (Mo)

[0059] Molybdenum (Mo) may improve hardenability up to 10 times greater than nickel (Ni) even with the addition of a small amount, and prevents temper brittleness, thereby providing resistance to temper brittleness. Since the molybdenum (Mo) forms carbides, the molybdenum (Mo) also has an excellent effect as an alloy element for high-grade cutting tools and raises a crystal grain coarsening temperature. The molybdenum (Mo) is more effective to improve hardenability when used in combination with chromium than used alone, but has a disadvantage of high cost.

[0060] At this time, the high-performance steel bar according to an embodiment of the present disclosure may preferably include 0.002 to 0.10 wt% of molybdenum (Mo).

Aluminum (Al)

[0061] Aluminum (Al) serves as a strong deoxidizer during steel manufacturing to control oxidative non-metallic inclusions within the steel, but excessive aluminum (Al) addition, may increase non-metallic inclusions, leading to manufacturing problems such as nozzle clogging, so that it is necessary to control the amount to be added.

[0062] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.005 to 0.040 wt% of aluminum (Al).

Vanadium (V)

[0063] Vanadium (V) is a representative micro-alloying element with a high carbide-forming ability, which helps to refine the structure of steel and improve the strength and toughness, and contributes to strength improvement by forming precipitates with a small amount of addition. However, vanadium oxide (V_2O_5), which is an oxide, has a high vapor pressure and evaporates at high temperatures, and thus may be added in an amount of 0.10 wt% or less.

[0064] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.10 wt% or less (excluding 0) of vanadium (V), preferably 0.05 wt% or less of vanadium (V), more preferably 0.003 to 0.040 wt% of vanadium (V).

Niobium (Nb)

[0065] Niobium (Nb) segregates or precipitates at the grain boundaries of austenite crystal grains to cause a solute drag effect and a pinning effect, and as a result, serves to delay a recrystallization phenomenon during hot rolling to increase a recrystallization stop temperature, thereby contributing to the crystal grain refinement of the final ferrite. In addition, the niobium (Nb) helps to improve the strength by forming fine precipitates. However, when added with more than 0.10 wt%, the niobium (Nb) may cause coarse precipitation and resulting carbon deficiency within general crystal grains, which may lower the strength.

[0066] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.10 wt% or less (excluding 0) of niobium (Nb), preferably 0.05 wt% or less (excluding 0) of niobium (Nb), more preferably 0.003 to 0.040 wt% of niobium (Nb).

Titanium (Ti)

[0067] Titanium (Ti) is an element that contributes to strength improvement by combining with carbon (C) and nitrogen (N) contained in steel to form carbide (TiC), nitride (TN), or carbonitride (TiCN). However, when added with more than 0.1 wt%, the coarsening of carbides may cause nozzle clogging during casting or a decrease in strength and ductility due to carbon deficiency in the steel.

[0068] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.001 to 0.050 wt% of titanium (Ti).

Nitrogen (N)

[0069] Nitrogen (N) has a significant effect on the mechanical properties of steel even in an extremely small amount, and increases tensile strength and yield strength while decreasing elongation. In particular, a decrease in impact value

and an increase in transition temperature are significant. The nitrogen (N) contributes to the formation of fine-grained steel by making austenite crystal grains fine, and refines the crystal grains by forming nitrides with titanium, zirconium, vanadium, niobium, etc., but a large amount of nitrogen (N) may reduce high-temperature toughness, and induce intergranular brittleness as well as reduce high-temperature creep strength due to the precipitation of AlN in the austenite grain boundaries.

[0070] To this end, the high-performance steel bar according to an embodiment of the present disclosure may include 0.015 wt% or less (excluding 0) of nitrogen (N).

[0071] In addition, the high-performance steel bar according to an embodiment of the present disclosure may further include at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).

Tin (Sn)

[0072] Tin (Sn) may increase the tensile strength and yield strength of steel and decrease the elongation and impact value. The tin (Sn) may cause red-hot brittleness, temper brittleness, and low-temperature brittleness during hot working, and improve corrosion resistance.

[0073] To this end, the high-performance steel bar according to an embodiment of the present disclosure may include 0.15 wt% or less of tin (Sn).

Magnesium (Mg)

[0074] Magnesium (Mg) easily forms fine inclusions or precipitates while having a stronger affinity with oxygen (O₂) or sulfur (S) than titanium (Ti), etc., thereby contributing to improvement of deoxidation and cleanliness, and improvement of strength.

[0075] Considering this, the high-performance steel bar according to an embodiment of the present disclosure may include 0.10 wt% or less of magnesium (Mg).

Calcium (Ca)

[0076] Calcium (Ca) is a strong deoxidizer and induces the formation of CaS from MnS inclusions formed during steelmaking, and thus does not elongate like MnS during rolling to prevent a decrease in mechanical properties even if separated through floatation or remaining.

[0077] At this time, the high-performance steel bar according to an embodiment of the present disclosure may include 0.05 wt% or less of calcium (Ca).

[0078] Meanwhile, in the high-performance steel bar according to an embodiment of the present disclosure, due to a hot precipitation strengthening effect of stable vanadium (V)-based nitrides and a solute drag effect and a pinning effect of niobium (Nb), the initial grain growth of austenite is delayed. This leads to an increase of a recrystallization stop temperature, at which recrystallization does not occur, thereby delaying the recrystallization phenomenon during hot rolling.

[0079] Ultimately, a low ductile-brittle transition temperature (DBTT) may be secured through the grain size refinement of the final ferrite, thereby satisfying stability and economic feasibility at cryogenic temperatures.

[0080] At this time, the DBTT refers to a temperature at which a metallic material having brittle characteristics at low temperatures rapidly transforms into a ductile material while atomic diffusion becomes easier with increasing temperature and a potential slip effect occur actively, leading to an increase in the inherent ductility, and it may be determined that the lower the temperature, the better the low-temperature toughness.

[0081] Accordingly, in the high-performance steel bar according to an embodiment of the present disclosure, the recrystallization stop temperature at which recrystallization does not occur due to hot deformation may increase by the addition of micro-alloying elements, vanadium (V) and niobium (Nb).

[0082] Particularly, in the high-performance steel bar according to an embodiment of the present disclosure, when hot deformation is applied below the recrystallization stop temperature, instead of continuous dynamic recrystallization of austenite, pancake-shaped grains are formed, and thus as the final ferrite grain size is refined, the grain boundary fraction per unit area is increased.

[0083] At this time, in the high-performance steel bar according to an embodiment of the present disclosure, as the grain boundary fraction per unit area increases, fine ferrite may be formed while the number of nucleation sites during phase transformation increases, and cryogenic stability may be maximized through the ultrafine-grained ferrite formed above.

[0084] Here, the ferrite structure may include polygonal ferrite and acicular ferrite, and the average grain size of the ferrite structure may be 5.0 to 13.2 μm , preferably 5.0 to 8.0 μm , more preferably 5.0 to 7.5 μm .

[0085] Meanwhile, low-temperature toughness may be determined through the average grain size and the DBTT of the ferrite. According to an embodiment of the present disclosure, the DBTT may be -41°C or lower, preferably -50 to -75°C .

[0086] In other words, it can be confirmed that the high-performance steel bar according to an embodiment of the present disclosure may have excellent low-temperature toughness by securing a significantly low DBTT together with a ferrite structure with a fine grain size.

[0087] In addition, the high-performance steel bar according to an embodiment of the present disclosure may have a notch sensitivity ratio (NSR) at -170°C of 1.02 or higher.

[0088] The high-performance steel bar according to an embodiment of the present disclosure may have a final microstructure including polygonal ferrite, bainite, acicular ferrite, and pearlite.

Manufacturing method of high-performance steel bar

[0089] FIG. 1 is a flowchart illustrating a process sequence of a manufacturing method of a high-performance steel bar according to an embodiment of the present disclosure.

[0090] FIG. 2 shows final microstructure images of Comparative Material and Inventive Material.

[0091] Referring to FIG. 1, a manufacturing method of a high-performance steel bar according to an embodiment of the present disclosure includes (a) a reheating step, (b) a hot rolling step, and (c) a cooling step.

[0092] More specifically, the manufacturing method may include: (a) reheating a steel material including 0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and the balance of iron (Fe) and inevitable impurities; (b) hot rolling the steel material by controlling a rolling start temperature to 950 to 1100°C and a rolling end temperature to 800 to 1000°C ; and (c) cooling the steel material.

[0093] Here, the steel material may be an ingot or a billet produced by a continuous casting process performed before the reheating step. Therefore, the alloying elements included in the steel material and the composition range of the alloying elements may be understood as being included in the same manner in a high-performance steel bar manufactured through the ingot or the billet.

[0094] At this time, the reason for controlling the rolling end temperature, which is a hot deformation finishing temperature range of the steel material, to 800 to 1000°C is to promote phase transformation through hot deformation below the recrystallization stop temperature to ultimately form a fine ferrite structure.

[0095] That is, according to the delay in initial grain growth of austenite caused by the hot precipitation strengthening effect of stable vanadium (V)-based nitrides and the solute drag and pinning effects of niobium (Nb), the recrystallization stop temperature at which recrystallization does not occur due to hot deformation is increased, and when the deformation is applied below the recrystallization stop temperature, the final ferrite grain size is refined by continuous dynamic recrystallization of austenite, thereby increasing the grain boundary fraction per unit area.

[0096] Through this, it is possible to refine the ferrite by increasing the number of nucleation sites during the phase transformation of the steel material, and to maximize cryogenic stability through the ultrafine-grained ferrite formed above.

[0097] Ultimately, it is possible to significantly lower the DBTT when obtaining a fine grain size of ferrite.

[0098] In addition, in step (a), a recrystallization stop temperature (RST) of the steel material may increase depending on the delay in initial grain growth of austenite.

[0099] At this time, in step (b), the rolling end temperature, which is the hot deformation finishing temperature range of the steel material, may be controlled to be below the recrystallization stop temperature of the steel material.

[0100] In addition, in step (c), the steel material may be cooled by accelerate control cooling (ACC). At this time, the accelerate control cooling (ACC) is a cooling process that induces internal and external structural changes of the steel material by spraying a temp core and water, which is a cooling medium, at high pressure/uniformly in the middle of the final cooling completion step immediately after the hot deformation of the steel material.

[0101] In the manufacturing method of the high-performance steel bar according to an embodiment of the present disclosure, in step (c), the steel material may be cooled at a cooling rate of 30 to $400^{\circ}\text{C}/\text{sec}$.

[0102] In addition, in the manufacturing method of the high-performance steel bar according to an embodiment of the present disclosure, in step (c), the steel material may be cooled to a final cooling temperature (recuperative temperature) of 500 to 700°C .

[0103] Ultimately, the manufacturing method of the high-performance steel bar according to an embodiment of the present disclosure may implement a steel bar with a structure satisfying high strength and low-temperature toughness even at cryogenic temperatures by controlling the recuperative and cooling temperatures through accelerate control

cooling (ACC) after hot deformation of the steel material.

[0104] At this time, the steel material that has undergone step (c) enables the refinement of ferrite by increasing the number of nucleation sites through phase transformation as the grain boundary fraction per unit area increases, so that the average grain size of the ferrite structure may be 5.0 to 13.2 μm , preferably 5.0 to 8.0 μm , more preferably 5.0 to 7.5 μm .

[0105] The steel material that has undergone step (c) may have a final microstructure including polygonal ferrite, acicular ferrite, pearlite, and bainite, as shown in FIG. 2.

[0106] In addition, the steel material that has undergone step (c) may secure a ductile-brittle transition temperature (DBTT) of -41°C or lower, preferably -50 to -75°C by implementing a ferrite structure with a fine grain size.

[0107] In addition, the high-performance steel bar manufactured by the manufacturing method described above within the compositional range of the alloying components described above may satisfy yield strength of at least 1.15 times greater than room temperature yield strength in a cryogenic environment of -165 to -170°C , a uniform elongation of 3% or higher, and a notch sensitivity ratio (NSR) of 1.0 or higher, preferably an NSR of 1.02 or higher.

Comparative Examples and Experimental Examples

[0108] Hereinafter, preferred Comparative Examples and Experimental Examples will be presented in order to assist the understanding of the present disclosure. However, the following Experimental Examples are intended only to aid in understanding the present disclosure, and the present disclosure is not limited by the following Experimental Examples.

[0109] Tables 1 and 2 below show major alloy compositions (unit: wt%) constituting inventive materials of Experimental Examples and comparative materials of Comparative Examples, Table 3 below shows operating conditions for manufacturing each specimen of Experimental Examples and Comparative Examples, and Tables 4 and 5 show results of measuring the mechanical properties of specimens implemented according to the operating conditions for manufacturing each specimen of Experimental Examples and Comparative Examples.

[0110] The mechanical properties of the comparative material and the inventive material were measured in accordance with KS D 3504 and ISO 15630-1 standards.

[0111] The 'YS' item represents yield strength, the 'TS' item represents tensile strength, the 'EL' item represents elongation, the 'UE' item represents uniform elongation, and the 'NSR' item represents a notch sensitive ratio, a value calculated as a ratio of (tensile strength of a notched specimen) to (yield strength of an un-notched specimen) in which the 'un' mark represents an un-notched specimen, and the 'n' mark indicates a notched specimen. Room temperature corresponds to 25°C .

[Table 1]

Classification	Chemical component (wt%)								
	C	Si	Mn	P	S	Cu	Cr	Mo	Ni
Comparative Material 1	0.07	0.15	1.63	0.010	0.010	0.15	0.20	0.02	0.57
Comparative Material 2	0.27	0.12	1.00	0.026	0.024	0.23	0.11	0.02	0.02
Comparative Material 3	0.07	0.12	0.75	0.010	0.010	0.23	0.10	0.05	0.60
Inventive Material 1	0.13	0.22	1.37	0.015	0.010	0.20	0.10	0.02	0.16
Inventive Material 2	0.08	0.27	1.44	0.009	0.005	0.10	0.10	0.01	0.17
Inventive Material 3	0.08	0.30	1.48	0.009	0.002	0.13	0.15	0.03	0.17
Inventive Material 4	0.07	0.30	1.49	0.008	0.002	0.20	0.08	0.02	0.18
Inventive Material 5	0.10	0.33	1.48	0.009	0.001	0.16	0.11	0.01	0.04

[Table 2]

Classification	Chemical component (wt%)					CEQ	RST
	V	Nb	Al	Ca	N		
Comparative Material 1	0.002	0.003	0.002	0.002	0.009	0.43	843
Comparative Material 2	0.003	0.002	0.015	0.001	0.010	0.48	950
Comparative Material 3	0.002	0.001	0.015	0.001	0.010	0.28	861

(continued)

Classification	Chemical component (wt%)					CEQ	RST
	V	Nb	Al	Ca	N		
Inventive Material 1	0.002	0.018	0.025	0.001	0.004	0.41	901
Inventive Material 2	0.001	0.013	0.020	0.001	0.003	0.36	841
Inventive Material 3	0.001	0.017	0.024	0.002	0.006	0.38	847
Inventive Material 4	0.001	0.014	0.029	0.003	0.005	0.36	833
Inventive Material 5	0.037	0.038	0.037	0.002	0.008	0.39	947

[0112] Referring to Tables 1 and 2 above, Comparative Materials 1 to 3 contain 0.003 wt%, 0.002 wt%, and 0.001 wt% of niobium (Nb), respectively, and Inventive Materials 1 to 5 contain 0.018 wt%, 0.013 wt%, 0.017 wt%, 0.014 wt%, and 0.038 wt% of niobium (Nb), respectively.

[0113] In addition, Comparative Materials 1 to 3 contain 0.002 wt%, 0.003 wt%, and 0.002 wt% of vanadium (V), respectively, and Inventive Materials 1 to 5 contain 0.002 wt%, 0.001 wt%, 0.001 wt%, 0.001 wt%, and 0.037 wt% of vanadium (V), respectively.

[0114] A difference in niobium (Nb) content affects the recrystallization stop temperature (RST). At this time, due to the solute drag effect and the pinning effect of niobium (Nb), the initial grain growth of austenite is delayed, thereby raising the recrystallization stop temperature at which recrystallization due to hot deformation does not occur. As such, Inventive Materials may achieve the refinement of the average grain size of ferrite crystal grains and improve room-temperature elongation and low-temperature toughness compared to Comparative Materials by adding vanadium (V) and niobium (Nb) and increasing the contents thereof, as shown in Table 4 below.

[0115] More specifically, compared to Comparative Materials, Inventive Materials exhibit an increased recrystallization stop temperature at which recrystallization does not occur due to the addition of high contents of vanadium (V) and niobium (Nb), which induce the hot precipitation strengthening effect of stable V-based nitrides and a solute drag effect of Nb, thereby delaying initial grain growth of austenite and when deformation is applied below the recrystallization stop temperature, continuous dynamic recrystallization of austenite occurs, resulting in the refinement of the final ferrite grain size and an increase in the grain boundary fraction per unit area. Through this, it is possible to refine the ferrite structure by increasing the number of nucleation sites during the phase transformation, and to maximize cryogenic stability through the ultrafine-grained ferrite formed above.

[Table 3]

Classification	Diameter	Operating condition			
		Rolling start temperature (°C)	Rolling end temperature (°C)	Cooling water amount (m ³ /hr)	Recuperative temperature (°C)
Comparative Material 1	D16	1050	Performed above each recrystallization stop temperature (RST) with-in range of 900 to 1000°C	1005	520
	D32	1050		1005	573
Comparative Material 2	D25	1100		1005	585
Comparative Material 3	D32	1100		1005	585
Inventive Material 1	D16	1050	Performed below each recrystallization stop temperature (RST) with-in range of 800 to 1000°C	1005	525
	D32	1050		1005	569
Inventive Material 2	D16	1050		1005	523
	D32	1050		1005	571
Inventive Material 3	D25	1050		720	565
Inventive Material 4	D25	1050		720	580
Inventive Material 5	D25	1050		720	598

[Table 4]

Classification	Diameter	Room-temperature mechanical property		Grain size	Low-temperature roughness
		YS (MPa)	EL (%)	Average grain size of Ferrite (μm)	DBTT ($^{\circ}\text{C}$)
Comparative Material 1	D16	553	18.4	13.3	-40
	D32	540	17.4		
Comparative Material 2	D25	575	12.5	12.6	-21
Comparative Material 3	D25	457	13.6	12.1	-28
Inventive Material 1	D16	583	26.3	7.2	-53
	D32	547	24.0		
Inventive Material 2	D16	562	27.2	6.8	-59
	D32	557	25.7		
Inventive Material 3	D25	588	26.6	7.1	-59
Inventive Material 4	D25	567	24.3	6.8	-59
Inventive Material 5	D25	566	24.0	5.1	-72

[Table 5]

Classification	Diameter	Low-temperature mechanical property (-170°C)			
		YS_un (MPa)	UE_un (%)	TS_n (MPa)	NSR
Comparative Material 1	D16	808	9.2	825	1.02
	D32	776	7.1	792	1.02
Comparative Material 2	D25	822	4.1	756	0.92
Comparative Material 3	D25	742	9.3	705	0.95
Inventive Material 1	D16	821	10.2	846	1.03
	D32	796	8.7	812	1.02
Inventive Material 2	D16	781	10.4	813	1.04
	D32	755	9.2	778	1.03
Inventive Material 3	D25	759	9.6	794	1.05
Inventive Material 4	D25	757	9.9	794	1.05
Inventive Material 5	D25	1,016	16.7	1025	1.01

[0116] Referring to Tables 1 to 5 above, Comparative Materials 1 to 3 and Inventive Materials 1 to 5 are specifically compared and will be described.

[0117] In Comparative Materials 1 to 3, final finishing rolling was performed at a temperature exceeding the recrystallization stop temperature (RST) of each Comparative Material within the rolling end temperature range of 900 to 100 $^{\circ}\text{C}$, which was the hot deformation finishing temperature.

[0118] In addition, in Inventive Materials 1 to 5, the final finishing rolling was performed at a temperature below the recrystallization stop temperature (RST) of each Comparative Material within the rolling end temperature range of 800 to 1000 $^{\circ}\text{C}$, which was the hot deformation finishing temperature.

[0119] At this time, in Comparative Materials, the final finishing rolling was performed at a rolling end temperature higher than the recrystallization stop temperature (RST), so that the average grain size in the ferrite structure was coarsely formed.

[0120] However, in Inventive Materials, the final finishing rolling was performed at a rolling end temperature controlled to the recrystallization stop temperature (RST) or lower, so that the average grain size in the ferrite structure was very finely formed.

[0121] This fact can be confirmed in FIG. 2, and referring to FIG. 2, it can be easily visually confirmed that the final structure of Comparative Materials has a coarse grain size, whereas it can be confirmed that the final structure of Inventive Materials has a very fine grain size.

[0122] A difference in the average grain size of the ferrite structure affects the low-temperature toughness of the steel bar, and the ductile-brittle transition temperature (DBTT) of Comparative Materials was -40°C or higher, but Inventive Materials had stable low-temperature impact performance of -50 to -75°C, so that it was confirmed that the low-temperature impact performance was improved compared to Comparative Materials.

[0123] Meanwhile, it can be confirmed that the elongation (EL) at room temperature of Inventive Materials 1 to 5 is also greater than that of Comparative Materials 1 to 3.

[0124] In addition, it can be confirmed that the uniform elongation (UE_{un}) of the un-notch specimens of Invention Materials 1 to 5 is also higher than that of Comparative Materials 1 to 3.

[0125] In addition, it can be confirmed that the notch sensitivity ratio (NSR), which is the value of tensile strength (TS_n)/yield strength (YS_{un}) at -170°C, is also superior in Invention Materials compared to Comparative Materials.

[0126] As described above, the prepared embodiment of the present disclosure has been as described, and in addition to the embodiments described above, a fact that the present disclosure can be materialized in other specific forms without departing from the gist or scope thereof will be apparent to those skilled in the art. Therefore, the aforementioned embodiments are not limited but should be considered to be illustrative, and accordingly, the present disclosure is not limited to the above description and may be modified within the scope of the appended claims and a range equivalent thereto.

Claims

1. A high-performance steel bar comprising:

0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and a balance of iron (Fe) and inevitable impurities, wherein a room-temperature yield strength (YS) is 500 MPa or higher.

2. The high-performance steel bar of claim 1, further comprising:

at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).

3. The high-performance steel bar of claim 1, wherein an average grain size of a ferrite structure is 5.0 to 13.2 μm.

4. The high-performance steel bar of claim 1, wherein a ductile-brittle transition temperature (DBTT) is -41°C or lower.

5. The high-performance steel bar of claim 1, wherein a final microstructure includes polygonal ferrite, acicular ferrite, pearlite, and bainite.

6. The high-performance steel bar of claim 1, wherein an elongation at room temperature is 14% or more.

7. A manufacturing method of a high-performance steel bar comprising:

(a) reheating a steel material including 0.08 to 0.26 wt% of carbon (C), 0.50 wt% or less (excluding 0) of silicon (Si), 0.6 to 3.0 wt% of manganese (Mn), 0.025 wt% or less (excluding 0) of phosphorus (P), 0.025 wt% or less (excluding 0) of sulfur (S), 0.002 to 0.50 wt% of chromium (Cr), 0.50 wt% or less (excluding 0) of copper (Cu), 0.01 to 3.40 wt% of nickel (Ni), 0.002 to 0.10 wt% of molybdenum (Mo), 0.005 to 0.040 wt% of aluminum (Al), 0.10 wt% or less (excluding 0) of vanadium (V), 0.1 wt% or less (excluding 0) of niobium (Nb), 0.001 to 0.050 wt% of titanium (Ti), 0.015 wt% or less (excluding 0) of nitrogen (N), and a balance of iron (Fe) and inevitable impurities;

(b) hot rolling the steel material by controlling a rolling start temperature to 950 to 1100°C and a rolling end temperature to 800 to 1000°C; and

(c) cooling the steel material.

- 5 8. The manufacturing method of the high-performance steel bar of claim 7, wherein the steel material further includes at least one of 0.15 wt% or less of tin (Sn), 0.10 wt% or less of magnesium (Mg), and 0.05 wt% or less of calcium (Ca).
9. The manufacturing method of the high-performance steel bar of claim 7, wherein in step (b), the rolling end temperature is controlled below a recrystallization stop temperature of the steel material.
- 10 10. The manufacturing method of the high-performance steel bar of claim 7, wherein step (c) is performed by accelerate control cooling, which is cooled at a cooling rate of 30 to 400°C/sec, and cooled to a final cooling temperature of 500 to 700°C.
- 15 11. The manufacturing method of the high-performance steel bar of claim 7, wherein the steel bar that has undergone step (c) has an average grain size of a ferrite structure of 5.0 to 13.2 μm .
12. The manufacturing method of the high-performance steel bar of claim 7, wherein the steel bar that has undergone step (c) has a ductile-brittle transition temperature (DBTT) of -41°C or lower.
- 20 13. The manufacturing method of the high-performance steel bar of claim 7, wherein the steel bar that has undergone step (c) has a final microstructure including polygonal ferrite, acicular ferrite, pearlite, and bainite.

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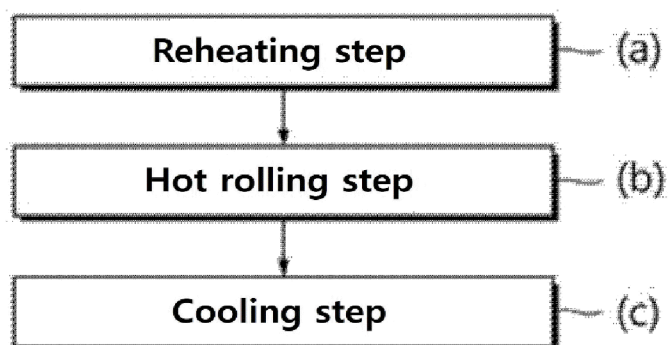
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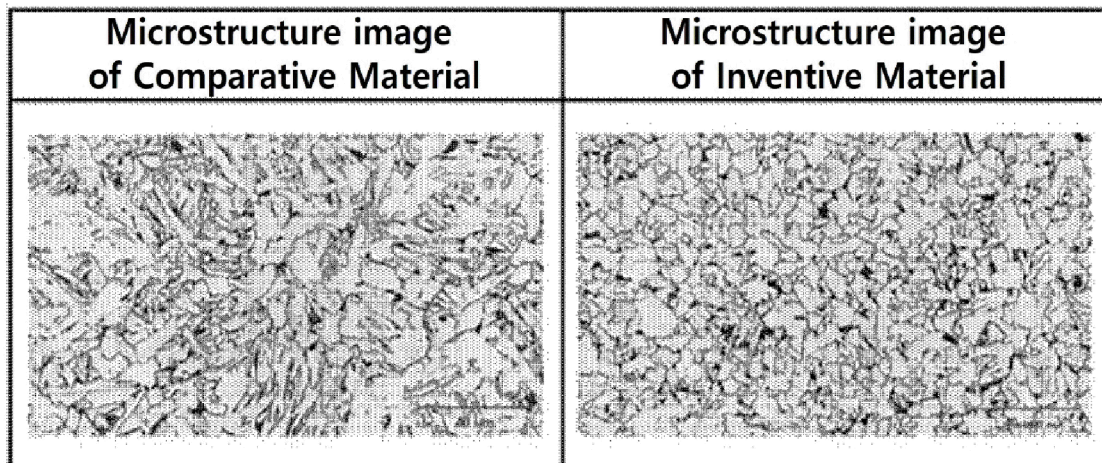
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【Fig. 1】



【Fig. 2】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/018945

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/44**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/46**(2006.01)i;
C22C 38/48(2006.01)i; **C22C 38/50**(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 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01);
C22C 38/16(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: 인성(toughness), 연성(ductility), 고강도(high strength), 재결정온도(recrystallization temperature), 결정립(crystal grain)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2022-0082041 A (JFE STEEL CORPORATION) 16 June 2022 (2022-06-16) See paragraphs [0011] and [0140], table 3, and claims 1-3 and 5.	1-13
X	KR 10-0833035 B1 (POSCO) 27 May 2008 (2008-05-27) See tables 2-3 and claims 1-2.	1-13
X	KR 10-2003-0081050 A (NIPPON STEEL CORPORATION) 17 October 2003 (2003-10-17) See table 3 and claims 1 and 6.	1-13
A	JP 5644522 B2 (NIPPON STEEL & SUMITOMO METAL) 24 December 2014 (2014-12-24) See claims 1-4.	1-13
A	US 2016-0010193 A1 (JFE STEEL CORPORATION) 14 January 2016 (2016-01-14) See claims 1-4.	1-13

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

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“&” document member of the same patent family

Date of the actual completion of the international search 26 February 2025	Date of mailing of the international search report 27 February 2025
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

International application No.

PCT/KR2024/018945

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
L	PCT/KR2024/18944 has the same priority date as the present application(PCT/KR2024/018945), and claims 1-6 of both applications are identical. (Therefore, PCT/KR2024/018944 is related to category "L".)	1-6

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/018945

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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2022-0082041 A	16 June 2022	CA 3152893 A1	27 May 2021
		CN 114729426 A	08 July 2022
		CN 114729426 B	23 June 2023
		EP 4029962 A1	20 July 2022
		JP 6973681 B2	01 December 2021
		KR 10-2727026 B1	05 November 2024
		TW 202129024 A	01 August 2021
		TW I758956 B	21 March 2022
		US 12139780 B2	12 November 2024
		US 2022-0396856 A1	15 December 2022
		WO 2021-100534 A1	27 May 2021
KR 10-0833035 B1	27 May 2008	None	
KR 10-2003-0081050 A	17 October 2003	CA 2424491 A1	09 October 2003
		CA 2424491 C	23 September 2008
		DE 60301588 T2	22 June 2006
		EP 1354973 A1	22 October 2003
		EP 1354973 B1	14 September 2005
		JP 2003-293089 A	15 October 2003
		JP 3869747 B2	17 January 2007
		KR 10-0558429 B1	10 March 2006
		US 2003-0217795 A1	27 November 2003
		US 8070887 B2	06 December 2011
JP 5644522 B2	24 December 2014	JP 2012-144799 A	02 August 2012
US 2016-0010193 A1	14 January 2016	CN 105008569 A	28 October 2015
		CN 105008569 B	08 March 2017
		EP 2963138 A1	06 January 2016
		EP 2963138 B1	10 April 2019
		JP 5910792 B2	27 April 2016
		JP WO2014-132627 A1	02 February 2017
		KR 10-1737255 B1	17 May 2017
		KR 10-2015-0119208 A	23 October 2015
		US 10041159 B2	07 August 2018
		WO 2014-132627 A1	04 September 2014

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