(19) Europäisches
Patentamt
European
Patent Office
Office européen
des brevets

(11) EP 3 872 216 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
26.02.2025 Bulletin 2025/09

(21) Application number: **19876795.6**

(22) Date of filing: **25.10.2019**

(51) International Patent Classification (IPC):
C22C 38/38 $^{(2006.01)}$ ***C22C 38/20*** $^{(2006.01)}$
C22C 38/32 $^{(2006.01)}$ ***C22C 38/02*** $^{(2006.01)}$
C22C 38/06 $^{(2006.01)}$ ***C21D 9/46*** $^{(2006.01)}$
C21D 8/02 $^{(2006.01)}$ ***C21D 6/00*** $^{(2006.01)}$
C21D 1/02 $^{(2006.01)}$

(52) Cooperative Patent Classification (CPC):
**C21D 9/46; C21D 1/02; C21D 6/00; C21D 6/002;
C21D 6/005; C21D 8/02; C21D 8/0205;
C21D 8/0226; C21D 8/0231; C21D 8/0263;
C22C 38/02; C22C 38/06; C22C 38/20;
C22C 38/32; C22C 38/38;** (Cont.)

(86) International application number:
PCT/KR2019/014193

(87) International publication number:
WO 2020/085861 (30.04.2020 Gazette 2020/18)

---

(54) CRYOGENIC AUSTENITIC HIGH-MANGANESE STEEL HAVING EXCELLENT SHAPE, AND MANUFACTURING METHOD THEREFOR

KRYOGENER AUSTENITISCHER STAHL MIT HOHEM MANGANANTEIL UND AUSGEZEICHNETER FORM UND VERFAHREN ZUR HERSTELLUNG DAVON

ACIER AUSTÉNITIQUE CRYOGÉNIQUE À HAUTE TENEUR EN MANGANÈSE AYANT UNE EXCELLENTE FORME, ET PROCÉDÉ DE FABRICATION ASSOCIÉ

---

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **25.10.2018 KR 20180128504**
26.09.2019 KR 20190118925

(43) Date of publication of application:
01.09.2021 Bulletin 2021/35

(73) Proprietor: **POSCO Co., Ltd**
Pohang-si, Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
- **LEE, Un-Hae**
  Gwangyang-si,
  Jeollanam-do 57807 (KR)
- **KIM, Bo-Sung**
  Pohang-si,
  Gyeongsangbuk-do 37877 (KR)
- **SEOK, Jeong-Hun**
  Pohang-si,
  Gyeongsangbuk-do 37877 (KR)
- **LEE, Dong-Ho**
  Gwangyang-si,
  Jeollanam-do 57807 (KR)
- **KIM, Sung-Kyu**
  Gwangyang-si,
  Jeollanam-do 57807 (KR)
- **KANG, Sang-Deok**
  Gwangyang-si,
  Jeollanam-do 57807 (KR)

(74) Representative: **Meissner Bolte Partnerschaft mbB**
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

(56) References cited:
WO-A1-2017/111510 **WO-A1-2018/117712**
CN-A- 106 222 554 **CN-A- 107 177 786**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Processed by Luminess, 75001 PARIS (FR)

(Cont. next page)

CN-A- 107 620 010	**CN-A- 108 570 541**
JP-A- 2007 126 715	**JP-A- 2007 126 715**
KR-A- 20130 088 331	**KR-A- 20180 072 967**
KR-A- 20180 074 450	**KR-A- 20180 074 450**

(52) Cooperative Patent Classification (CPC): (Cont.)
C21D 2211/001

Description

[Technical Field]

[0001] The present invention relates to an austenitic high-manganese steel material and a method of manufacturing the same, and more particularly, to a cryogenic austenitic high-manganese steel material having excellent cryogenic toughness and an excellent shape, and a manufacturing method thereof.

[Background Art]

[0002] An austenitic high-manganese steel material has high toughness because austenite is stable even in room temperature and cryogenic environment by adjusting contents of manganese (Mn) and carbon (C), which are elements increasing stability of austenite, so that it has particularly suitable properties as a material for cryogenic structures such as tanks for LNG storage, tanks for LNG transport, and the like.

[0003] However, high-manganese steel has high deformation resistance at high temperatures, and particularly, in the case of thin materials, it is difficult to secure a uniform shape in a longitudinal direction according to a rolling pass, a reduction ratio, and the like. If a shape of the hot-rolled material is poor, a cooling safety is lowered, and there is a possibility of causing equipment damage in a process such as transportation. In addition, when the shape of the hot-rolled material in the longitudinal direction is poor, a subsequent operation such as a shape correction operation, or the like, must be undertaken, which is not preferable in terms of economy and productivity. Further, since there is a technical limitation in securing a uniform shape even through an additional shape correction operation after cooling, or the like, a high-manganese steel material having excellent shape uniformity and a manufacturing method thereof are required without requiring an additional operation such as shape fixing.

[0004] CN106222554 A discloses an economic ultra-low temperature high manganese austenitic steel, having excellent low-temperature toughness.

(Prior art document)

[0005]

(Patent Document 1) Korean Registered Patent Publication Korean Registered Patent Publication No. 10-1994-0002370 (published on February 17, 1994)
(Patent Document 2) CN106222554 A

[Disclosure]

[Technical Problem]

[0006] According to the present invention a cryogenic austenitic high-manganese steel material having an excellent shape and a method of manufacturing the same is provided.

[Technical Solution]

[0007] The invention is defined in the appended claims.

[0008] various features of the present invention and advantages and effects thereof will be understood in more detail with reference to the specific embodiments as below.

[Advantageous Effects]

[0009] According to the present invention, it is possible to provide an austenitic high-manganese steel material having excellent cryogenic toughness and an excellent shape, and a method of manufacturing the same.

[Description of Drawings]

[0010] FIG. 1 (a) is a view to help in understanding a crest and a trough formed in a steel material in the present disclosure, and FIG. 1 (b) is a view is an image captured of a steel material according to an example of the present disclosure.

[Best Mode for Invention]

[0011] The present invention relates to a cryogenic austenitic high-manganese steel material having an excellent shape and a method of manufacturing the same, and hereinafter, preferable embodiments of the present invention will be described. Embodiments of the present invention may be modified in various forms, and the scope of the present invention should not be construed as being limited to the embodiments described below. These embodiments are provided to further describe the present invention to a person skilled in the art to which the present invention pertains.

[0012] Hereinafter, a steel composition in the present invention will be described in greater detail. Hereinafter, "%," indicating a content of each element, may be based on weight, unless otherwise indicated.

[0013] The cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure includes by weight %, 0.2 to 0.5% of C, 23 to 28% of Mn, 0.05 to 0.5 % of si, 0.3 to 1% of Cu 0.03% or less of P, 0.005% or less of S, 0.05
to 0.5% of Al, 2.5 to 4.5% of Cr, 0.0005 to 0.01% of B, and a remainder of Fe and other unavoidable impurities.

Carbon (C): 0.2 to 0.5%

[0014] Carbon (C) is effective in stabilizing austenite and securing strength by solid solution strengthening. Accordingly, in the present disclosure, a lower limit of the carbon (C) content is limited to 0.2% to secure low-temperature toughness and strength. That is, when the carbon (C) content is less than 0.2%, austenite stability may be insufficient such that stable austenite may not be obtained at cryogenic temperature, and processing organic transformation into ε-martensite and α'-martensite may easily occur by external stress such that toughness and strength of the steel material may be reduced. On the other hand, when the carbon (C) content exceeds a certain range, toughness of the steel material may be rapidly deteriorated due to precipitation of carbides, and strength of the steel material may increase excessively such that workability of the steel material may significantly degrade. Thus, an upper limit of the carbon (C) content is limited to 0.5%. Therefore, the carbon (C) content in the present disclosure may be 0.2 to 0.5%. A preferable carbon (C) content is 0.3 to 0.5%, and a more preferable carbon (C) content may be 0.3 to 0.45%.

Manganese (Mn): 23% to 28%

[0015] Manganese (Mn) is an element effectively contributing to austenite stabilization, and thus, in the present disclosure, a lower limit of the manganese (Mn) content is limited to 23% to achieve such an effect. In other words, since 23% or more of manganese (Mn) is included in the present disclosure, stability of austenite may effectively increase, such that the formation of ferrite, ε-martensite, and α'-martensite may be inhibited, thereby effectively securing low-temperature toughness of the steel material. On the other hand, when the manganese (Mn) content exceeds a certain level, an effect of increasing stability of austenite may be saturated, but manufacturing costs may greatly increase, and internal oxidation may excessively occur during hot-rolling, such that surface quality may be deteriorated. Thus, in the present disclosure, an upper limit of the manganese (Mn) content is limited to 28%. Accordingly, the manganese (Mn) content in the present disclosure is 23 to 28%, and a more preferable manganese (Mn) content may be 23 to 25%.

Silicon (Si): 0.05 to 0.50%

[0016] Silicon (Si)is a deoxidizing agent as aluminum (Al) and is inevitably added in a small amount. However, when silicon (Si) is excessively added, an oxide may be formed on a grain boundary such that high-temperature ductility may be reduced, and cracks may be created such that surface quality may be deteriorated. Thus, in the present disclosure, an upper limit of the silicon (Si) content is limited to 0.5%. Since excessive costs may be required to reduce the silicon (Si) content in steel, a lower limit of the silicon (Si) content is limited to 0.05% in the present disclosure. Therefore, the silicon (Si) content in the present disclosure is 0.05 to 0.5%.

Copper (Cu): 0.3 to 1%

[0017] Copper (Cu) is an element stabilizing austenite together with manganese (Mn) and carbon (C), and effectively contributes to improving low-temperature toughness. Also, copper (Cu) has an extremely low solubility in carbides and is slowly diffused in austenite, such that copper (Cu) may be concentrated on an interfacial surface between austenite and carbide and may surround a nuclei of fine carbide, thereby effectively inhibiting formation and growth of carbides caused by additional diffusion of carbon (C). Thus, in the present disclosure, copper (Cu) is essentially added to secure low-temperature toughness, and a lower limit of the copper (Cu) content is 0.3%. On the other hand, when the copper (Cu) content exceeds 1%, hot workability of the steel material may be deteriorated, and in the present disclosure, an upper limit of the copper (Cu) content is limited to 1%. A more preferable upper limit of the copper (Cu) content may be 0.8%.

Phosphorus (P): 0.03% or less

[0018] Phosphorus (P) is not only an impurity element that is unavoidably introduced, but is also an element that easily segregates and causes cracking during casting, or an element that deteriorates weldability. Accordingly, in the present disclosure, an upper limit of the phosphorus (P) content is limited to 0.03% to prevent deterioration of castability and weldability.

Sulfur (S): 0.005% or less

[0019] Sulfur (S) is not only an impurity element that is unavoidably introduced, but is also an element that causes a hot brittleness defect by forming inclusions. Accordingly, in the present disclosure, an upper limit of the sulfur (S) content is limited to 0.005% to inhibit hot brittleness.

Aluminum (Al): 0.05 to 0.5%

[0020] Aluminum (Al) is a representative element added as a deoxidizer. However, aluminum (Al) may form precipitates by reacting with carbon (C) and nitrogen (N), and hot workability may be deteriorated by the precipitates. Thus, in the present disclosure, an upper limit of the aluminum (Al) content is limited to 0.5%. The aluminum (Al) content is 0.05 to 0.5%.

Chromium (Cr): 2.5% to 4.5%

[0021] Chromium (Cr) may stabilize austenite in a range of an appropriate amount such that chromium (Cr) may contribute to improving impact toughness at low temperature, and may be solid-solute in austenite and may increase strength of the steel material. Also, chromium may improve corrosion resistance of the steel material. Therefore, in the present disclosure, 2.5% or more of chromium (Cr) is added to obtain the effect as above. However, chromium (Cr) may be a carbide-forming element and may form carbides on an austenite grain boundary, such that low-temperature impact toughness may be reduced. Thus, an upper limit of the chromium (Cr) content is limited to 4.5% in consideration of content relationship between carbon (C) and other elements added together. Accordingly, the chromium (Cr) content in the present disclosure is 2.5 to 4.5%, and a more preferable chromium (Cr) content may be 3 to 4%.

Boron (B): 0.0005% to 0.01%

[0022] Boron (B) is a grain boundary strengthening element which may strengthen an austenite grain boundary, and by even adding boron (B) in a small amount, an austenite grain boundary may be strengthened such that high-temperature cracking sensitivity may be effectively reduced. To achieve the effect as above, in the present disclosure, a lower limit of the boron (B) content is limited to 0.0005%. On the other hand, when the boron (B) content exceeds a certain range, segregation may occur on an austenite grain boundary such that high-temperature cracking sensitivity of the steel material may increase, and surface quality of the steel material may be degraded. Thus, in the present disclosure, an upper limit of the boron (B) content is limited to 0.01%. The boron (B) content of the present disclosure is 0.0005 to 0.01%, and a more preferable boron (B) content may be 0.002 to 0.006%.

[0023] The cryogenic austenitic high-manganese steel having an excellent shape of the present disclosure has a remainder of Fe and other unavoidable impurities in addition to the above components. However, in a general manufacturing process, inevitable impurities may be inevitably added from raw materials or an ambient environment, and thus, impurities may not be excluded. A person skilled in the art of a general manufacturing process may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure.

[0024] The cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure may include 95 area% or more of austenite as a microstructure, thereby effectively securing cryogenic toughness of the steel material. An average grain size of austenite may be 5-150 μm. An average grain size of austenite implementable in the manufacturing process may be 5 μm or more, and when the average grain size increases significantly, strength of the steel material may be reduced. Thus, the grain size of austenite may be limited to 150 μm or less.

[0025] The cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure may include a carbide and/or ε-martensite as a possible structure other than austenite. When a fraction of carbide and/or ε-martensite exceeds a certain level, toughness and ductility of the steel material may be rapidly deteriorated. Thus, in the present disclosure, the fraction of carbide and/or ε-martensite may be limited to 5 area% or less.

[0026] The cryogenic austenitic high-manganese steel material having an excellent shape according to the present invention has a yield strength of 350 MPa or more, a tensile strength of 700 MPa or more, and an elongation of 40% or more. In addition, the cryogenic austenitic high-manganese steel material having an excellent shape according to the present invention has a Charpy impact toughness of -196°C of 30J or more (based on a thickness of 5mm), and thus can have excellent cryogenic properties.

[0027] Since the cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present invention has a maximum height difference within 10 mm between the a crest and a trough formed in the steel material in a region within 2m of the rolling direction even without performing a separate correction operation after the steel material is manufactured, excellent shape uniformity may be secured.

[0028] FIG. 1 (a) is a view to help in understanding a crest and a trough formed in a steel material in the present disclosure, and FIG. 1 (b) is an image captured of a steel material according to an example of the present disclosure.

[0029] Hereinafter, a manufacturing method in the present disclosure will be described in more detail.

[0030] A method of manufacturing a cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure includes: primarily heating a slab including, by weight%, 0.2 to 0.5% of C, 23 to 28% of Mn, 0.05 to 0.5% of Si, 0.3 to 1% of Cu, 0.03% or less of P, 0.005% or less of S, 0.05 to 0.5% of Al, 2.5 to 4.5% of Cr, 0.0005 to 0.01% of B, and a remainder of Fe and unavoidable impurities, to a temperature range of 1050 to 1300°C; primarily hot-rolling the heated slab at a finishing rolling temperature of 800 to 1100°C at a total rolling reduction ratio of 35 to 80% to provide an intermediate material;

cutting the intermediate material into a length of 1500 to 4000 mm; secondarily heating the intermediate material to a temperature range of 1050 to 1300°C; secondarily hot-rolling the secondarily-heated intermediate material at a finishing rolling temperature of (Tnr-120) to Tnr°C to provide a hot- rolled material; and cooling the hot-rolled material to a temperature range of 600°C or less at a cooling rate of 1 to 100°C/s, wherein, during the secondary hot-rolling, a total rolling reduction amount of the intermediate material in the temperature range of (Tnr-120) to Tnr°C may be controlled to 5 to 25%.

Primary heating slab

[0031] Since the composition of the slab provided in the manufacturing method in the present disclosure corresponds to the steel composition of the austenitic high-manganese steel material described above, the description of the steel composition of the slab is replaced with the description of the steel composition of the austenitic high-manganese steel material described above.

[0032] The slab provided in the above-described steel composition is primarily heated in a temperature range of 1050 to 1300°C. When a primary heating temperature is lower than a certain range, there may be a problem in which an excessive rolling load may be applied during primary hot-rolling, or an alloy component may not be sufficiently solid solute. Therefore, in the present disclosure, a lower limit of the primary heating temperature range is limited to 1050°C. On the other hand, when the primary heating temperature exceeds a certain range, grains may grow excessively such that strength of the steel material may be deteriorated, or the steel material may be heated by exceeding a solidus temperature of the steel material such that hot-rolling properties of the steel material may be deteriorated. Thus, an upper limit of the primary heating temperature range of slab is limited to 1300°C.

Primary hot-rolling

[0033] A primary hot-rolling process may include a rough-rolling process and a finishing rolling process, and the primarily-heated slab may be size-rolled during the first hot-rolling and may be provided as an intermediate material. A total reduction ratio of the primary hot-rolling is 35 to 80%, and the finishing rolling of the primary hot-rolling is performed in a temperature range of 800 tc 1100°C. When the finishing hot-rolling temperature of the primary hot-rolling is less than a certain range, an excessive rolling load due to an increase in rolling load may be a problem, and when the finishing hot-rolling temperature of the primary hot-rolling exceeds a certain range, grains may grow coarse and the target strength cannot be obtained.

Primary heating intermediate material

[0034] In order to load an intermediate material into a heating furnace, the intermediate material is cut to a length of 1500 to 4000 mm. When the length of the intermediate material is less than 1500mm, tracking in the heating furnace is difficult, and when the length of the intermediate material exceeds 4000mm, there may be a risk of bending in a longitudinal direction.

[0035] The intermediate material is secondarily heated in a temperature range of 1050 to 1300°C. When a secondary heating temperature is lower than a certain range, there may be a problem in which an excessive rolling load may occur during the secondary hot-rolling, or a problem in that the alloy component is not sufficiently dissolved may occur. Thus, in the present disclosure, a lower limit of the secondary heating temperature range is limited to 1050°C. On the other hand, when the secondary heating temperature exceeds a certain range, grains may grow excessively such that strength of the steel material may be deteriorated, or the steel material may be heated by exceeding a solidus temperature of the steel material such that hot-rolling properties of the steel material may be deteriorated. Thus, in the present disclosure, an upper limit of the secondary heating temperature range of the intermediate material is limited to 1300°C.

Secondary hot-rolling

[0036] A secondary hot-rolling process may include a rough-rolling process and a finishing-rolling process, and the secondarily-reheated intermediate material is provided as an intermediate material by secondary hot-rolling. In this case, the finishing rolling is performed in a temperature range of (Tnr-120) to Tnr°C. Here, Tnr can be derived by Equation 1 below.

[Equation 1]

$$Tnr(°C) = 840 + 150*C + 2.5*Mn + 5*Cu + 3.5*Cr - 50*Si$$

(where, C, Mn, Cu, Cr, and Si are weight percentages of each component).

[0037] When a finishing rolling temperature of the secondary hot rolling is less than (Tnr-120)°C, strength increases rapidly and the impact toughness tends to be deteriorated. When the finishing rolling temperature of the secondary hot rolling exceeds Tnr°C, grains may grow excessively such that strength of the steel material may be deteriorated. Thus, in the present disclosure, the finishing rolling temperature of the secondary hot rolling is limited to a range of (Tnr-120) to Tnr °C.

[0038] In addition, in the present disclosure, a total rolling reduction amount of the intermediate material in the temperature range of (Tnr-120) to Tnr°C during the secondary hot rolling is controlled to 5 to 25%. When the total rolling reduction amount of the intermediate material in the temperature range of (Tnr-120) to Tnr°C is less than 5%, the desired shape correction effect cannot be achieved, and when the total rolling reduction amount of the intermediate material in the temperature range of (Tnr-120) to Tnr°C exceeds 25%, there is a concern about a decrease in impact toughness due to excessive reduction.

Cooling

[0039] The secondarily hot-rolled material is cooled to a cooling stop temperature of 600°C or less at a cooling rate of 1 to 100°C/s. When the cooling rate is less than a certain range, a decrease in ductility of the steel material and deterioration of abrasion resistance may become problems due to carbides precipitated on a grain boundary during cooling, and thus, in the present disclosure, the cooling rate the hot-rolled material is limited to 1°C/s or more. A lower limit of the preferred cooling rate may be 10°C/s, and a cooling method may be accelerated cooling. The higher the cooling rate is, the more advantageous the effect of inhibiting carbide precipitation may be, but in consideration of a situation in which it may be difficult to implement a cooling rate exceeding 100°C/s in general cooling in terms of characteristics of facility, an upper limit of the cooling rate is limited to 100°C/s in the present disclosure.

[0040] Also, even when a hot-rolled material is cooled by applying a cooling rate of 10°C/s or more, when the cooling is stopped at a high temperature, it may be highly likely that carbides may be created and grown, and thus, in the present disclosure, the cooling stop temperature is limited to 600°C or less.

[0041] The austenitic high-manganese steel material manufactured as above may include 95 area% or more of austenite. The austenitic high-manganese steel material has yield strength of 350 MPa or more, tensile strength of 700 MPa or more, elongation of 40% or more, and Charpy impact toughness of 30 J or more (based on a thickness of 5 mm) at -196°C.

[0042] In addition, the austenitic high-manganese steel material manufactured as described above has a maximum height difference of within 10 mm or less between a crest and a trough formed in the steel material in an area within 2 m in the longitudinal direction of the steel material, so that excellent shape uniformity can be ensured.

[Mode for Invention]

[0043] Hereinafter, the present invention will be described in more detail through examples. However, it is necessary to note that the following examples are only intended to illustrate the present invention in more detail and are not intended to limit the scope of the present invention. This is because the scope of the present invention is determined by matters described in the claims.

(Example)

[0044] A slab having an alloy composition of Table 1 below and a thickness of 250mm was manufactured. Each slab was primarily heated in a temperature range of 1200°C and then primarily hot-rolled at a finishing rolling temperature of 1000°C with a total rolling reduction ratio of 50 to 60% to prepare an intermediate material. Each intermediate material was subjected to secondary heating and secondary hot-rolling under the conditions of Table 2 to prepare a hot-rolled material specimen, and yield strength, tensile strength, elongation, Charpy impact toughness, and shape uniformity for each specimen were measured and shown in Table 3 below. In this case, shape uniformity was described by measuring a maximum height difference between a crest and a trough formed in an area within 2mm in a rolling direction of a specimen. Here, tensile properties were tested at room temperature according to ASTM A370, and the impact toughness was also measured at -196°C by being processed into a 5mm-thick impact specimen according to the conditions of the same standard.

[Table 1]

	Alloy composition (weight %)								
Classification	C	Mn	Si	P	S	Al	Cu	Cr	B
Steel type 1	0.38	24.8	0.29	0.015	0.003	0.26	0.51	3.19	0.001 4
Steel type 2	0.42	25.2	0.25	0.014	0.002 9	0.31	0.48	3.34	0.001 5
Steel type 3	0.49	26.4	0.22	0.015	0.003 2	0.28	0.38	3.75	0.002 1
Steel type 4	0.57	27.3	0.26	0.016	0.003 1	0.28	1.12	3.82	0.002 2

[Table 2]

Steel type	Classification	Heating furnace temperature (°C)	Extraction temperature (°C)	Final width (mm)	Tnr (°C)	Tnr-120 (°C)	Secondary rolling end temperature (°C)	Tnr or less total reduction ratio (%)
Steel type 1	1-1	1216	1191	2400	958	838	955	2
	1-2						691	7.0
	1-3						880	11.0
	1-4						865	16.0
	1-5						870	22.0
	1-6						862	27.0
	1-7						871	32.0
	1-8						720	42.0
Steel type 2	2-1	1186	1176	2410	968	848	941	7.0
	2-2						951	7.8
	2-3						920	11.0
	2-4						790	15.0
	2-5						860	21.0
	2-6						853	23.0
	2-7						840	28.0
	2-8						860	37.0
	2-9						790	40.0
Steel type 3	3-1	1190	1178	2500	984	864	990	0
	3-2						961	6.4
	3-3						800	13.0
	3-4						912	13.5
	3-5						888	21.0

(continued)

Steel type	Classification	Heating furnace temperature (°C)	Extraction temperature (°C)	Final width (mm)	Tnr (°C)	Tnr-120 (°C)	Secondary rolling end temperature (°C)	Tnr or less total reduction ratio (%)
	3-6						895	24.5
	3-7						881	36.0
	3-8						803	41.5
	3-9						871	48.0
Steel type 4	4-1	1209	1182	2510	1000	880	921	5.0
	4-2						910	6.8
	4-3						882	9.0
	4-4						876	21.0
	4-5						791	31.0

[Table 3]

Steel type	Classification	Wave height (mm)	YS (MPa)	Ts (MPa)	El (%)	Impact toughness (J, @-196°C)	Classification
Steel type 1	1-1	12	370	790	68	49	CE
	1-2	25	582	861	48	24	
	1-3	2	402	807	65	48	IE
	1-4	4	461	831	48	40	
	1-5	6	450	801	55	41	
	1-6	8.1	540	860	50	28	CE
	1-7	7.9	561	872	42	25	
	1-8	7.6	598	878	41	21	
Steel type 2	2-1	3.5	381	733	61	51	IE
	2-2	3	394	747	56	45	
	2-3	5	415	769	63	48	
	2-4	9	591	926	42	27	CE
	2-5	4.2	468	826	52	40	IE
	2-6	7	434	784	54	43	
	2-7	6.5	581	881	48	28	CE
	2-8	6	601	921	41	25	
	2-9	6.3	610	935	42	20	
Steel type 3	3-1	3	346	695	65	45	CE
	3-2	4	391	741	59	48	IE
	3-3	7.5	598	925	44	28	CE
	3-4	5.5	446	802	51	41	IE
	3-5	7.2	438	788	56	43	
	3-6	9	451	806	49	42	

(continued)

Steel type	Classification	Wave height (mm)	YS (MPa)	Ts (MPa)	El (%)	Impact toughness (J, @-196°C)	Classification
	3-7	8	554	898	46	28	CE
	3-8	7	531	881	47	27	
	3-9	6.5	595	915	40	26	
Steel type 4	4-1	9	590	941	45	20	
	4-2	11	610	940	44	21	
	4-3	20	625	949	42	14	
	4-4	4	640	965	41	10	
	4-5	9.7	685	1020	39	14	

[0045] As shown in Tables 2 and 3, the alloy composition and manufacturing process of the disclosure secures the desired physical properties and shape uniformity of the present disclosure in the case of a satisfactory invention example, but does not satisfy the alloy composition or manufacturing process of the present invention in the case of a comparative example.

[0046] In the case of the Comparative example, it can be seen that the present invention does not secure the desired physical properties and shape uniformity.

[0047] In the above, the present invention has been described in detail through Examples, but other types of Examples are also possible.

Claims

1. A cryogenic austenitic high-manganese steel material having an excellent shape, comprising, by weight%, 0.2 to 0.5 % of C, 23 to 28 % of Mn, 0.05 to 0.5 % of Si, 0.3 to 1 % of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.05 to 0.5 % of Al, 2.5 to 4.5 % of Cr, and 0.0005 to 0.01 % of B, with a remainder of Fe and other unavoidable impurities,

   wherein Charpy impact toughness at -196°C measured according to ASTM A370 standard is at least 30 J, based on a thickness of 5 mm, a yield strength of 350 MPa or more, a tensile strength of 700 MPa or more, and an elongation of 40% or more, wherein yield strength, tensile strength and elongating are measured according to ASTM A370 standard, and
   a maximum height difference between a crest and a trough formed within an area of 2 m in a rolling direction is at most 10 mm.

2. The cryogenic austenitic high-manganese steel material having an excellent shape of claim 1, wherein a grain size of the austenite is 5 to 150μm.

3. A method of manufacturing a cryogenic austenitic high-manganese steel material having an excellent shape of claim 1, comprising:

   primarily heating a slab including, by weight %, 0.2 to 0.5 % of C, 23 to 28 % of Mn, 0.05 to 0.5 % of Si, 0.3 to 1 % of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.05 to 0.5 % of Al, 2.5 to 4.5 % of Cr, and 0.0005 to 0.01 % of B, with a remainder of Fe and other unavoidable impurities to a temperature range of 1050 to 1300°C
   primarily hot-rolling the heated slab at a finishing rolling temperature of 800 to 1100°C at a total rolling reduction ratio of 35 to 80% to provide an intermediate material;
   cutting the intermediate material into a length of 1500 to 4000 mm,
   secondarily heating the cut intermediate material to a temperature range of 1050 to 1300°C;
   secondarily hot-rolling the secondarily-heated intermediate material at a finishing rolling temperature of (Tnr-120) to Tnr°C to provide a hot-rolled material;
   cooling the hot-rolled material to a temperature range of 600°C or less at a cooling rate of 1 to 100°C/s,
   wherein during the secondary hot-rolling, the total rolling reduction amount of the intermediate material in the temperature range of (Tnr-120) to Tnr°C is 5 to 25%, and
   wherein Tnr is derived by the following Equation 1:

$$\text{[Equation 1]}$$

$$Tnr(°C) = 840 + 150*C + 2.5*Mn + 5*Cu + 3.5*Cr - 50*Si$$

where C, Mn, Cu, Cr, and Si are weight percentages of each component.

Patentansprüche

1. Kryogener austenitischer Stahl mit hohem Mangananteil und ausgezeichneter Form, umfassend in Gewichts-% 0,2 bis 0,5 % C, 23 bis 28 % Mn, 0,05 bis 0,5 % Si, 0,3 bis 1 % Cu, 0,03 % oder weniger P, 0,005 % oder weniger S, 0,05 bis 0,5 % Al, 2,5 bis 4,5 % Cr und 0,0005 bis 0,01 % B, mit einem Rest aus Fe und anderen unvermeidbaren Verunreinigungen,
wobei die Charpy-Kerbschlagzähigkeit bei -196 °C, gemessen nach dem Standard ASTM A370, basierend auf einer Dicke von 5 mm, einer Streckgrenze von 350 MPa oder mehr, einer Zugfestigkeit von 700 MPa oder mehr und einer Dehnung von 40 % oder mehr mindestens 30 J beträgt, wobei die Streckgrenze, die Zugfestigkeit und die Dehnung nach dem Standard ASTM A370 gemessen werden und ein maximaler Höhenunterschied zwischen einem Scheitel und einem Tal, die innerhalb eines Bereichs von 2 m in einer Walzrichtung gebildet werden, höchstens 10 mm beträgt.

2. Kryogener austenitischer Stahl mit hohem Mangananteil und ausgezeichneter Form nach Anspruch 1, wobei eine Korngröße des Austenits 5 bis 150 μm beträgt.

3. Verfahren zur Herstellung eines kryogenen austenitischen Stahls mit hohem Mangananteil und ausgezeichneter Form nach Anspruch 1, umfassend:

   primäres Erwärmen einer Bramme, enthaltend in Gewichts-% 0,2 bis 0,5 % C, 23 bis 28 % Mn, 0,05 bis 0,5 % Si, 0,3 bis 1 % Cu, 0,03 % oder weniger P, 0,005 % oder weniger S, 0,05 bis 0,5 % Al, 2,5 bis 4,5 % Cr und 0,0005 bis 0,01 % B, mit einem Rest aus Fe und anderen unvermeidbaren Verunreinigungen, auf einen Temperaturbereich von 1050 bis 1300 °C;
   primäres Warmwalzen der erwärmten Bramme bei einer Fertigwalztemperatur von 800 bis 1100 °C mit einem Gesamtwalzreduktionsverhältnis von 35 bis 80 %, um ein Zwischenmaterial bereitzustellen;
   Schneiden des Zwischenmaterials auf eine Länge von 1500 bis 4000 mm;
   sekundäres Erwärmen des geschnittenen Zwischenmaterials auf einen Temperaturbereich von 1050 bis 1300 °C;
   sekundäres Warmwalzen des sekundär erwärmten Zwischenmaterials bei einer Fertigwalztemperatur von (Tnr-120) bis Tnr°C, um ein warmgewalztes Material bereitzustellen;
   Abkühlen des warmgewalzten Materials auf einen Temperaturbereich von 600 °C oder weniger mit einer Abkühlgeschwindigkeit von 1 bis 100 °C/s,
   wobei während des sekundären Warmwalzens das Gesamtwalzreduktionsausmaß des Zwischenmaterials im Temperaturbereich von (Tnr-120) bis Tnr°C 5 bis 25 % beträgt, und
   wobei Tnr durch die folgende Gleichung 1 abgeleitet wird:

   $$\text{[Gleichung 1]}$$

   $$Tnr(°C) = 840 + 150*C + 2,5*Mn + 5*Cu + 3,5*Cr - 50*Si$$

   wobei C, Mn, Cu, Cr und Si Gewichtsprozente jeder Komponente sind.

Revendications

1. Matériau en acier austénitique cryogénique à haute teneur en manganèse ayant une excellente forme, comprenant, en % en poids, 0,2 à 0,5 % de C, 23 à 28 % de Mn, 0,05 à 0,5 % de Si, 0,3 à 1 % de Cu, 0,03 % ou moins de P, 0,005 % ou moins de S, 0,05 à 0,5 % d'Al, 2,5 à 4,5 % de Cr, et 0,0005 à 0,01 % de B, avec un reste de Fe et d'autres impuretés inévitables,

   dans lequel la résilience Charpy à -196 °C mesurée selon la norme ASTM A370 est d'au moins 30 J, d'après une épaisseur de 5 mm, une limite d'élasticité de 350 MPa ou plus, une résistance à la traction de 700 MPa ou plus, et

un allongement de 40 % ou plus, dans lequel la limite d'élasticité, la résistance à la traction et l'allongement sont mesurés selon la norme ASTM A370, et
une différence de hauteur maximale entre une crête et un creux formé au sein d'une zone de 2 m dans une direction de laminage est d'au plus 10 mm.

2. Matériau en acier austénitique cryogénique à haute teneur en manganèse ayant une excellente forme selon la revendication 1, dans lequel une taille de grain de l'austénite est de 5 à 150 μm.

3. Procédé de fabrication d'un matériau en acier austénitique cryogénique à haute teneur en manganèse ayant une excellente forme de la revendication 1, comprenant :

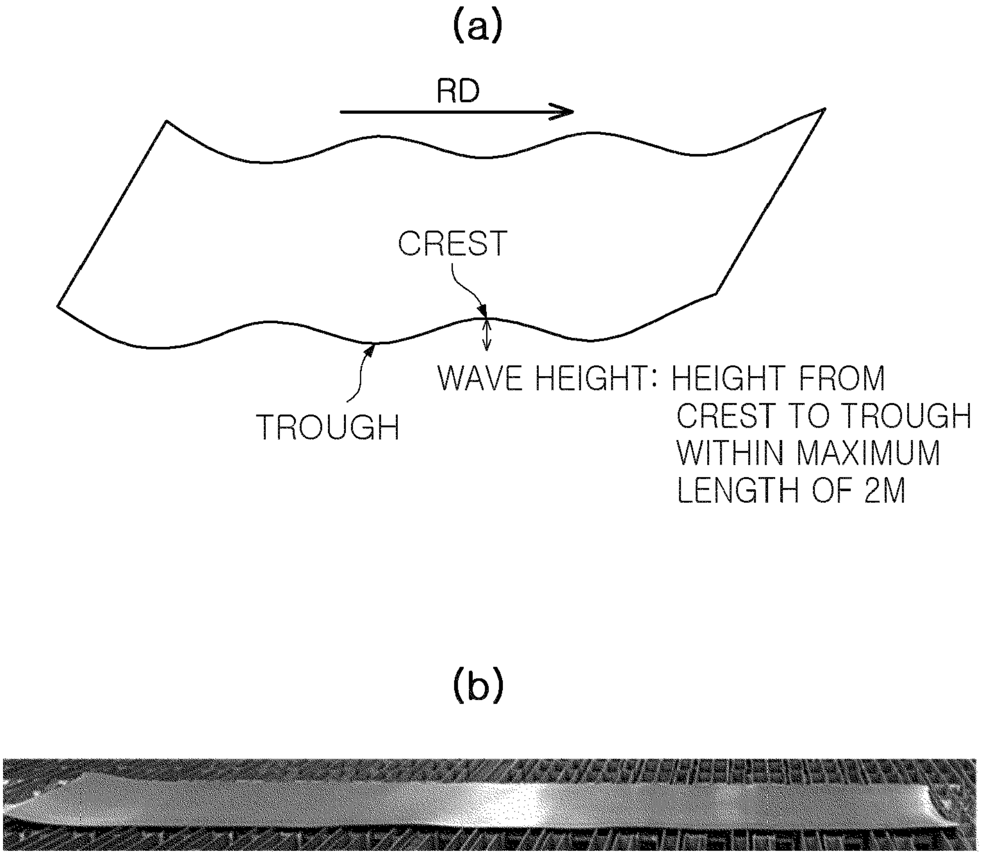
le chauffage primaire d'une brame incluant, en % en poids, 0,2 à 0,5 % de C, 23 à 28 % de Mn, 0,05 à 0,5°% de Si, 0,3 à 1°% de Cu, 0,03°% ou moins de P, 0,005°% ou moins de S, 0,05 à 0,5°% d'Al, 2,5 à 4,5°% de Cr, et 0,0005 à 0,01°% de B, avec un reste de Fe et d'autres impuretés inévitables, jusqu'à une plage de températures de 1050 à 1300 °C
le laminage à chaud primaire de la brame chauffée à une température de laminage de finition de 800 à 1100 °C à un taux de réduction de laminage totale de 35 à 80 % pour fournir un matériau intermédiaire ;
la découpe du matériau intermédiaire en une longueur de 1500 à 4000 mm,
le chauffage secondaire du matériau intermédiaire découpé jusqu'à une plage de températures de 1050 à 1300 °C ;
le laminage à chaud secondaire du matériau intermédiaire ayant subi un chauffage secondaire à une température de laminage de finition de (Tnr-120) à Tnr °C pour fournir un matériau laminé à chaud ;
le refroidissement du matériau laminé à chaud jusqu'à une plage de températures de 600 °C ou moins à une vitesse de refroidissement de 1 à 100 °C/s,
dans lequel, pendant le laminage à chaud secondaire, la quantité de réduction de laminage totale du matériau intermédiaire dans la plage de températures de (Tnr-120) à Tnr °C est de 5 à 25 %, et
dans lequel Tnr est dérivée de l'équation 1 suivante :

[Équation 1]

$$Tnr\ (°C) = 840 + 150*C + 2,5*Mn + 5*Cu + 3,5*Cr - 50*Si$$

où C, Mn, Cu, Cr et Si sont des pourcentages en poids de chaque composant.

[Fig. 1]


(a)
RD
CREST
TROUGH
WAVE HEIGHT: HEIGHT FROM CREST TO TROUGH WITHIN MAXIMUM LENGTH OF 2M
(b)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- CN 106222554 A **[0004] [0005]**
- KR 1019940002370 **[0005]**