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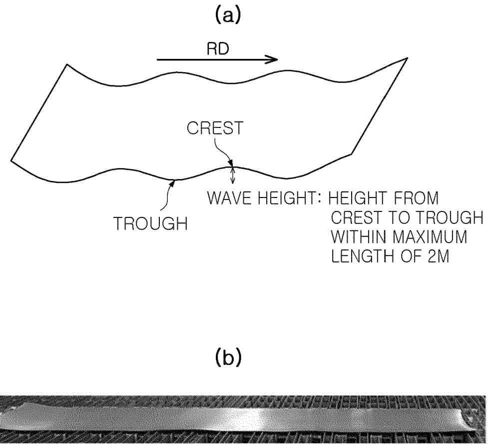
(54) CRYOGENIC AUSTENITIC HIGH-MANGANESE STEEL HAVING EXCELLENT SHAPE, AND MANUFACTURING METHOD THEREFOR

(57) The cryogenic austenitic high-manganese steel having an excellent shape, according to one aspect of the present invention, comprises 0.2-0.5 wt% of C, 23-28 wt% of Mn, 0.05-0.5 wt% of Si, 1 wt% or less (but not 0 wt%) of Cu, 0.03 wt% or less of P, 0.005 wt% or less of S, 0.5 wt% or less of Al, 2.5-4.5 wt% of Cr, and 0.0005-0.01 wt% of B, with the remainder being Fe and other unavoidable impurities, and also comprises at least 95 area% of austenite as a microstructure, wherein the Charpy impact toughness at - 196°C is least 30 J (based on a thickness of 5 mm), and the maximum difference in height between a crest and a trough formed within an area of 2 m along the direction of rolling may be at most 10 mm.

[Fig. 1]



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Description

[Technical Field]

[0001] The present disclosure 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.

(Prior art document)

[0004] (Patent Document 1) Korean Registered Patent Publication Korean Registered Patent Publication No. 10-1994-0002370 (published on February 17, 1994)

[Disclosure]

[Technical Problem]

[0005] According to an aspect of the present disclosure, a cryogenic austenitic high-manganese steel material having an excellent shape and a method of manufacturing the same may be provided.

[0006] The subject of the present disclosure is not limited to the above description. A person skilled in the art would have no difficulty in understanding the additional subject of the present disclosure from the overall description in the present specification.

[Technical Solution]

[0007] According to an aspect of the present disclosure, a cryogenic austenitic high-manganese steel material having an excellent shape, includes, by weight%, 0.2 to 0.5 % of C, 23 to 28 % of Mn, 0.05 to 0.5 % of Si, 1 % or less (excluding 0 %) of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.5 % or less of Al, 2.5 to 4.5 % of Cr, and 0.0005 to 0.01 % of B, and a remainder of Fe and other unavoidable impurities, and at least 95 area% of austenite as a microstructure, wherein Charpy impact toughness at -196°C is at least 30 J (based on a thickness of 5 mm), and a maximum height difference between a crest and a trough formed within an area of 2 m in a rolling direction may be, at most, 10 mm.

[0008] The austenite may have a grain size of 5 to 150 μm.

[0009] The steel material may have yield strength of 350 MPa or more, tensile strength of 700 MPa or more, and elongation of 40% or more.

[0010] According to an aspect of the present disclosure, a method of manufacturing cryogenic austenitic high-manganese steel material having an excellent shape 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, 1 % or less (excluding 0 %) of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.5 % or less of Al, 2.5 to 4.5 % of Cr, and 0.0005 to 0.01 % of B, and 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; 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; 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 controlled to 5 to 25%.

[0011] The hot-rolled material after cooling is completed may have a maximum height difference of within 10 mm between a crest and a trough formed in an area within 2 m in a rolling directionrolling direction.

[0012] The means for solving the above problems are not all of the features of the present disclosure, and various features of the present disclosure and advantages and effects thereof will be understood in more detail with reference to the specific embodiments as below.

[Advantageous Effects]

[0013] According to a preferred aspect of the present disclosure, 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]

[0014] 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]

[0015] The present disclosure 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 disclosure will be described. Embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as being limited to the embodiments described below. These embodiments are provided to further describe the present disclosure to a person skilled in the art to which the present disclosure pertains.

[0016] Hereinafter, a steel composition in the present disclosure will be described in greater detail. Hereinafter, "%," indicating a content of each element, may be based on weight, unless otherwise indicated.

[0017] The cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure may include, by weight %, 0.2 to 0.5% of C, 23 to 28% of Mn, 0.05 to 0.5% of Si, 1% or less of Cu (excluding 0%), 0.03% or less of P, 0.005% or less of S, 0.5% or less 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%

[0018] 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 may be 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 may be 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 may be 0.3 to 0.5%, and a more preferable carbon (C) content may be 0.3 to 0.45%.

Manganese (Mn): 23% to 28%

[0019] Manganese (Mn) is an element effectively contributing to austenite stabilization, and thus, in the present disclosure, a lower limit of the manganese (Mn) content may be 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 may be limited to 28%. Accordingly, the manganese (Mn) content in the present disclosure may be 23 to 28%, and a more preferable manganese (Mn) content may be 23 to 25%.

Silicon (Si): 0.05 to 0.50%

[0020] 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 may be 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 may be limited to 0.05% in the present disclosure. Therefore, the silicon (Si) content in the present disclosure may be 0.05 to 0.5%.

Copper (Cu): 1% or less (excluding 0%)

[0021] 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) may be essentially added to secure low-temperature toughness, and a preferable lower limit of the copper (Cu) content may be 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 may be limited to 1%. A more preferable upper limit of the copper (Cu) content may be 0.8%.

Phosphorus (P): 0.03% or less

[0022] 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 may be limited to 0.03% to prevent deterioration of castability and weldability.

Sulfur (S): 0.005% or less

[0023] 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 may be limited to 0.005% to inhibit hot brittleness.

Aluminum (Al): 0.5% or less

[0024] 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 may be limited to 0.5%. A more preferable aluminum (Al) content may be 0.05 to 0.5%.

Chromium (Cr): 2.5% to 4.5%

[0025] 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) may be 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 may be 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 may be 2.5 to 4.5%, and a more preferable chromium (Cr) content may be 3 to 4%.

Boron (B): 0.0005% to 0.01%

[0026] 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 may be 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 may be limited to 0.01%. The boron (B) content of the present disclosure may be 0.0005 to 0.01%, and a more preferable boron (B) content may be 0.002 to 0.006%.

[0027] The cryogenic austenitic high-manganese steel having an excellent shape according to an aspect of the present disclosure may include 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. Also, addition of effective elements other than the above composition may not be excluded.

[0028] 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.

[0029] 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.

[0030] The cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure may have 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 an aspect of the present disclosure 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.

[0031] Since the cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure 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.

[0032] 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.

[0033] Hereinafter, a manufacturing method in the present disclosure will be described in more detail.

[0034] A method of manufacturing a cryogenic austenitic high-manganese steel material having an excellent shape according to an aspect of the present disclosure may include: 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, 1% or less of Cu (excluding 0%), 0.03% or less of P, 0.005% or less of S, 0.5% or less 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; 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

[0035] 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 may be replaced with the description of the steel composition of the austenitic high-manganese steel material described above.

[0036] The slab provided in the above-described steel composition may be 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 may be 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 may be limited to 1300°C.

Primary hot-rolling

[0037] 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 may be 35 to 80%, and the finishing rolling of the primary hot-rolling is preferably performed in a temperature range of 800 to 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

[0038] In order to load an intermediate material into a heating furnace, the intermediate material may be cut to an appropriate length according to a thickness of the intermediate material, and preferably, the intermediate material may be 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.

[0039] The intermediate material may be 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 may be 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 may be limited to 1300°C.

Secondary hot-rolling

[0040] A secondary hot-rolling process may include a rough-rolling process and a finishing-rolling process, and the secondarily-reheated intermediate material may be provided as an intermediate material by secondary hot-rolling. In this case, the finishing rolling is preferably 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).

[0041] 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 may be limited to a range of (Tnr-120) to Tnr°C.

[0042] 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 may be 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

[0043] The secondarily hot-rolled material may be 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 may be 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 may be limited to 100°C/s in the present disclosure.

[0044] 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 may be limited to 600°C or less.

[0045] The austenitic high-manganese steel material manufactured as above may include 95 area% or more of austenite, and have 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.

[0046] 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]

[0047] Hereinafter, the present disclosure 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 disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by matters described in the claims and able to be reasonably inferred therefrom.

(Example)

[0048] 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
	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]

Stee l type	Clas sifi cati on	Wave heig ht (mm)	YS (MPa)	Ts (MPa)	El (%)	Impact toughness (J, @-196°C)	Classi ficati on
Stee l type	1-1	12	370	790	68	49	CE
	1-2	25	582	861	48	24	
	1-3	2	402	807	65	48	IE
1	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	
Stee l 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	
Stee l type 3	3-1	3	346	695	65	45	IE
	3-2	4	391	741	59	48	
	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	
	3-7	8	554	898	46	28	CE
	3-8	7	531	881	47	27	
	3-9	6.5	595	915	40	26	
Stee l 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	

[0049] 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 disclosure. In the case of the Comparative example, it can be seen that the present disclosure does not secure the desired physical properties and shape uniformity.

[0050] In the above, the present disclosure has been described in detail through Examples, but other types of Examples are also possible. Therefore, the technical spirit and scope of the claims set forth below are not limited to the Examples.

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, 1 % or less (excluding 0 %) of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.5 % or less 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, and at least 95 area% of austenite as a microstructure,
   wherein Charpy impact toughness at -196°C is at least 30 J (based on a thickness of 5 mm), 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. The cryogenic austenitic high-manganese steel material having an excellent shape of claim 1, wherein the steel material has yield strength of 350 MPa or more, tensile strength of 700 MPa or more, and elongation of 40% or more.

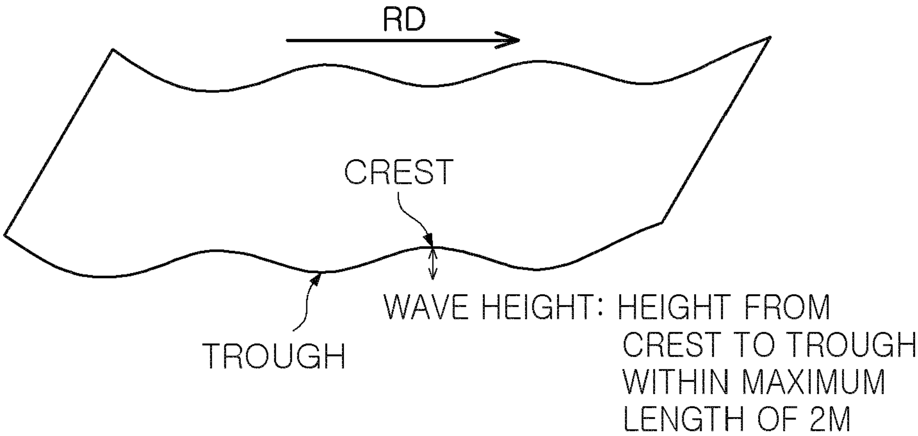
4. A method of manufacturing a cryogenic austenitic high-manganese steel material having an excellent shape, comprising:

   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, 1 % or less (excluding 0 %) of Cu, 0.03 % or less of P, 0.005 % or less of S, 0.5 % or less 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;
   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;
   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%.

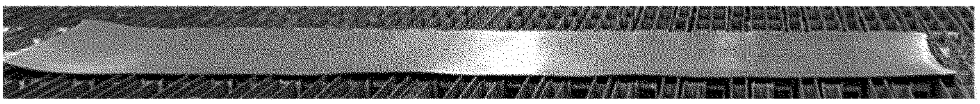
5. The method of manufacturing a cryogenic austenitic high-manganese steel material having an excellent shape of claim 5, wherein a hot-rolled material after the cooling is completed has a maximum height difference of within 10 mm, between a crest and a trough formed in an area within 2 m in a rolling direction.

[Fig. 1]

(a)


RD
CREST
TROUGH
WAVE HEIGHT: HEIGHT FROM
CREST TO TROUGH
WITHIN MAXIMUM
LENGTH OF 2M

(b)



INTERNATIONAL SEARCH REPORT	International application No. PCT/KR2019/014193

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i, C22C 38/20(2006.01)i, C22C 38/32(2006.01)i, C22C 38/02(2006.01)i, C22C 38/06(2006.01)i, C21D 8/02(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 38/38; C21D 8/02; C22C 38/00; C22C 38/02; C22C 38/04; C22C 38/20; C22C 38/32; C22C 38/06

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: high Mn, cryogenic, manganese(Mn), chrome(Cr), austenite

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-126715 A (SUMITOMO METAL IND LTD.) 24 May 2007 See claims 1-4 and tables 1, 3.	1-5
Y	CN 107620010 A (WUYANG IRON & STEEL CO., LTD.) 23 January 2018 See paragraph [0042] and claims 1, 3, 5-6.	1-5
A	KR 10-2018-0074450 A (POSCO) 03 July 2018 See claims 1-3.	1-5
A	KR 10-2013-0088331 A (HYUNDAI STEEL COMPANY) 08 August 2013 See claims 1-4.	1-5
A	KR 10-2018-0072967 A (POSCO) 02 July 2018 See claims 1, 4.	1-5

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

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 FEBRUARY 2020 (07.02.2020)	**07 FEBRUARY 2020 (07.02.2020)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2019/014193

Patent document cited in search report	Publication date	Patent family member	Publication date
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		EP 3561110 A1	30/10/2019
		KR 10-1940874 B1	21/01/2019
		US 2019-0323108 A1	24/10/2019
		WO 2018-117712 A1	28/06/2018

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 1019940002370 **[0004]**