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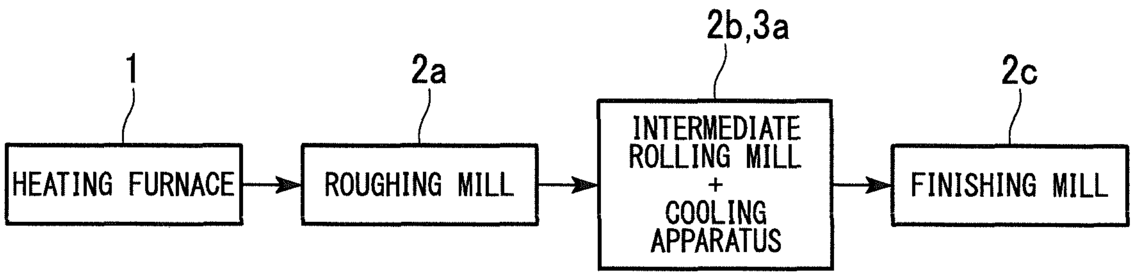
(54) H-SHAPED STEEL AND METHOD FOR PRODUCING SAME

(57) An H-section steel has a predetermined chemical composition, an Nb content and a B content satisfy Nb+125×B≥0.075%, a thickness of a flange is 12 mm to 40 mm, and in a thickness center portion and 1/4 flange width portion of the flange, a metallographic structure of a cross-section perpendicular to a rolling direction contains pearlite having a distribution density of 3.2×10^{-3} units/μm^2 or lower and the remainder is formed of ferrite and bainite.

FIG. 3



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Description

[Technical Field of the Invention]

[0001] The present invention relates to an H-section steel which is used in a structural member of a building used in a low temperature environment and a method of producing the same, and more particularly to an H-section steel for low temperature use having high strength and excellent toughness in a heat affected zone and a method of producing the same.

[0002] Priority is claimed on Japanese Patent Application No. 2013-094589, filed on April 26, 2013, the content of which is incorporated herein by reference.

[Related Art]

[0003] Recently, due to increasing worldwide energy demand, the demand for structures for use in energy-related facilities in cold regions has rapidly increased. As such a facility, for example, there is a Floating Production, Storage and Offloading System (FPSO), that is, a facility which produces offshore oil and gas, stores the oil and gas in a tank in the facility, and directly offloads the oil and gas onto a transport tanker. H-section steel used to build such a structure requires excellent low temperature toughness.

[0004] Hitherto, H-section steel has been used in a general building structure. For example, in Patent Documents 1 to 3, H-section steel having excellent toughness or fire resistance is suggested. In a general building structure, Charpy absorbed energy at about 0°C is required. However, in the H-section steel used in the energy-related facilities in cold regions, for example, Charpy absorbed energy at -40°C is required. Furthermore, in order to reasonably guarantee low temperature toughness, a CTOD value at -10°C needs to be specified as well as Charpy impact test properties (absorbed energy).

[0005] A crack tip opening displacement (CTOD) test is one of the tests used to evaluate the fracture toughness of a structure having a defect. When bending stress is applied to a test piece having a crack while maintaining a predetermined temperature, a phenomenon called "unstable fracture" in which a crack rapidly propagates, occurs. In the CTOD test, the crack tip opening amount (CTOD value) immediately before the crack rapidly propagates is measured. The CTOD value and the Charpy absorbed energy do not always have a good correlation therebetween.

[0006] In a case where H-section steel is produced by performing hot rolling on a cast slab obtained by continuous casting, it is difficult to ensure toughness by refining grains. This is because there is a limit to the maximum thickness of the cast slab that can be produced by a continuous casting facility and thus a rolling reduction ratio (the ratio of product thickness and cast slab thickness) cannot be sufficiently ensured. Furthermore, in order to increase the dimensional accuracy of a product, it is effective to perform rolling at a high temperature. However, when rolling is performed at a high temperature, in a flange portion or a fillet portion having a large thickness, the rolling temperature in particular is increased and the cooling rate is reduced. As a result, in the flange portion or the fillet portion, grains are coarsened, and there is concern that a reduction in toughness will occur. When accelerated cooling is performed after finishing the rolling, a structure having a certain degree of refinement can be obtained. However, high cost is required to introduce a cooling facility after rolling. In order to meet the demand for low temperature toughness, some of the inventors previously suggested H-section steel having excellent low temperature toughness, to which Nb and B are added, and a method of producing the same, in Patent Document 4.

[Prior Art Document]

[Patent Document]

[0007]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. H11-193440
[Patent Document 2] PCT International Publication No. WO2007/91725
[Patent Document 3] PCT International Publication No. WO2008/126910
[Patent Document 4] Japanese Patent Application No. 2011-274278

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0008] There are no problems related to the properties of the base metal of the H-section steel for low temperature use of the related art. However, the low temperature toughness of a heat affected zone (HAZ) has not been sufficiently examined. An object of the present invention is to provide H-section steel which has high strength and excellent low temperature toughness and also has excellent weldability and heat affected zone toughness (HAZ toughness) so as to be useable in a structure in cold regions, and a method of producing H-section steel, in which the H-section is produced without the need for a large-scale of cooling facilities. In addition, the H-section steel of the present invention is not a built-up H-section steel which is formed by welding a steel plate, but is a non-heat-treated rolled H-section steel which is formed by hot rolling, particularly, universal rolling and does not require a thermal refining treatment such as quenching or tempering.

[Means for Solving the Problem]

[0009] The inventors intensively studied how to solve the above-described problems. As a result, it was found that the reduction in toughness due to a mechanism of fracture from a structure which is formed of a carbide such as pearlite or cementite as the origin was significant. Therefore, the inventors focused on fractures due to carbide as the origin, in order to enhance low temperature toughness, and examined a method of suppressing the generation of carbide which is the origin of brittle fracture. As a result of the examination, by reducing carbon content in steel in order to suppress the generation of carbide and by allowing an appropriate amount of alloy elements such as Nb and B to be contained in order to generate bainite which is necessary to ensure strength, the inventors succeeded in enhancing the low temperature toughness of H-section steel without a reduction in strength. Furthermore, in order to allow the low temperature toughness of a heat affected zone to be at the same level as that of base metal before welding, it was found that it is important to suppress the fraction of a pearlite structure which is present in the base metal. In particular, the inventors found that by controlling the amounts of Nb and B to be in appropriate ranges, strength can be ensured even when the C content is reduced, and thus the generation of carbide which is the origin of fractures was suppressed, thereby enhancing the toughness of the base metal and the toughness of the heat affected zone.

[0010] Furthermore, the inventors found that in order to obtain a fine structure having good toughness, performing rolling while strictly suppressing the surface temperature of a flange is extremely effective. Specifically, it was found that during finish rolling, the rolling needs to be performed in one or more passes while the surface temperature of the flange is in a temperature range of 870°C or lower and 770°C or higher.

[0011] The present invention was completed on the basis of the above-described findings. In the H-section steel of the present invention, the generation of carbide which is the origin of brittle fracture was extremely suppressed and thus the low temperature toughness of the base metal and the heat affected zone was improved. The summary of the present invention is as follows.

[0012]

(1) That is, according to an aspect of the present invention, there is provided an H-section steel, in which a chemical composition thereof includes, in terms of mass%: C: 0.010% to 0.014%; Si: 0.05% to 0.50%; Mn: 0.8% to 2.0%; Cu: 0.01% or more and less than 0.60%; Ni: 0.01% or more and less than 0.50%; Al: more than 0.005% and 0.040% or less; Ti: 0.001% to 0.025%; Nb: 0.010% to 0.070%; N: 0.001% to 0.009%; O: 0.0005% to 0.0035%; B: more than 0.0003% and 0.0015% or less; V: 0% to 0.10%; Mo: 0% to 0.10%; Cr: 0% or more and less than 0.20%; Zr:0 to 0.030%; Hf:0 to 0.010%; REM:0 to 0.010%; and Ca:0 to 0.0050%; and an Nb content and a B content satisfy Expression 1, a thickness of a flange is 12 mm to 40 mm, and in a thickness center portion and 1/4 flange width portion of the flange, a metallographic structure of a cross-section perpendicular to a rolling direction contains a pearlite having a distribution density of 3.2×10^{-3} units/μm^2 or lower and the remainder consists of a ferrite and a bainite,

$$Nb+125\times B\geq 0.075\% \qquad \ldots\text{Expression 1},$$

and where Nb and B in Expression 1 are amounts of the elements in terms of mass%.

(2) In the H-section steel described in (1), a tensile strength may be 460 MPa to 550 MPa.

(3) In the H-section steel described in (1) or (2), the chemical composition may include, in terms of mass%, one or two or more types of: V: 0.01% to 0.10%; Mo: 0.01% to 0.10%; and Cr: 0.01% or more and less than 0.20%.

(4) In the H-section steel described in any one of (1) to (3), the chemical composition may include, in terms of mass%, one or two types of: Zr: 0.001% to 0.030%; and Hf: 0.001% to 0.010%.

(5) In the H-section steel described in any one of (1) to (4), the chemical composition may include, in terms of mass%, one or two types of: REM: 0.0001% to 0.010%; and Ca: 0.0001 % to 0.0050%.

(6) According to another aspect of the present invention, there is provided a method of producing an H-section steel,

including: a heating process of heating a steel slab having the chemical composition according to any one of claims 1 to 5 to 1100°C to 1350°C; a hot rolling process of performing a hot rolling on the steel slab into an H-section steel; and an air cooling process of performing an air cooling on the H-section steel, in which the hot rolling process includes a rough rolling process of rolling the steel slab by using a roughing mill, an intermediate rolling process of performing a reverse rolling by using an intermediate rolling mill, and a finish rolling process of performing a rolling by using a finishing mill, during the reverse rolling of the intermediate rolling process, a controlled rolling in which a rolling is performed while the H-section steel is cooled by using a water cooling apparatuses provided on a front surface and a rear surface of the intermediate rolling mill is performed, in the finish rolling process, the rolling is performed in one or more passes while a surface temperature of a flange is in a range of 770°C to 870°C, and a thickness of the flange is 12 mm to 40 mm.

[Effects of the Invention]

[0013] According to the above aspects of the present invention, the H-section steel for low temperature use having high strength and excellent low temperature toughness can be produced by rolling without performing accelerated cooling. As a result, a significant cost reduction due to a reduction in construction cost and a reduction of a construction period can be achieved. Furthermore, even when welding is performed on the H-section steel of the present invention, a reduction in the toughness of the heat affected zone is small and excellent low temperature toughness is provided. Therefore, the reliability of a large building used in cold regions can be enhanced without damage to the economic efficiency. Therefore, the present invention makes a significant contribution to industry.

[Brief Description of the Drawings]

[0014]

FIG. 1 is a view showing the cross-sectional shape of an H-section steel according to an embodiment of the present invention.
FIG. 2 is a view showing an example of a method of producing the H-section steel according to the embodiment of the present invention.
FIG. 3 is a view showing an example of a production apparatus which is used to heat and roll the H-section steel according to the embodiment of the present invention.

[Embodiments of the Invention]

[0015] Hereinafter, an H-section steel according to an embodiment of the present invention (hereinafter, also referred to as an H-section steel according to this embodiment) will be described in detail.
[0016] First, the chemical composition (component composition) of the H-section steel according to this embodiment will be described. Here, "%" for the components represents mass%.

(C: 0.010% to 0.014%)

[0017] C is an effective element for strengthening steel, and the lower limit of the C content is 0.010%. On the other hand, when the C content is more than 0.014%, HAZ toughness is degraded, and thus HAZ toughness at a low temperature cannot be sufficiently ensured. Particularly, in a case where the thickness of a flange is great (for example, 26 mm or greater), a pearlite structure is formed, and the pearlite structure is transformed into a martensite-island (martensite-austenite-constituent) structure after welding. The martensite-island structure becomes an embrittlement phase, resulting in the deterioration of HAZ toughness. Therefore, the upper limit of the C content is 0.014%. In a case of further enhancing the toughness and weld cracking resistances of base metal and a heat affected zone, the C content is preferably less than 0.014%.

(Si: 0.05% to 0.50%)

[0018] Si is a deoxidizing element, and contributes to strength enhancement. In order to obtain such an effect, the lower limit of the Si content is 0.05%. On the other hand, Si is an element which accelerates the generation of cementite. Therefore, the upper limit of the Si content is 0.50%. In order to suppress the generation of the martensite-island and further enhance the toughness of the base metal and the heat affected zone, the upper limit of the Si content is preferably 0.40%.

(Mn: 0.8% to 2.0%)

[0019] Mn is an element which increases the hardenability of steel, and is an effective element in accelerating the generation of bainite for ensuring the strength of the base metal. In order to obtain this effect, the lower limit of the Mn content is 0.8%. In order to further increase the strength of the base metal, the lower limit of the Mn content is preferably 1.0%, and is more preferably 1.3%. On the other hand, when the Mn content is more than 2.0%, the toughness, cracking properties, and the like of the base metal and the heat affected zone are deteriorated. Therefore, the upper limit of the Mn content is 2.0%.

(Cu: 0.01% or more and less than 0.60%)

[0020] Cu is an element which enhances the hardenability of steel and contributes to strengthening (increasing the strength) of the base metal through precipitation hardening. In a case where the Cu content is 0.01% or more, a Cu phase precipitates on the dislocation of ferrite when a temperature range in which ferrite is generated is held during rolling and mild cooling is performed, resulting in an increase in the strength. In order to obtain this effect, the lower limit of the Cu content is 0.01%. A preferable lower limit of the Cu content is 0.30%. On the other hand, when the Cu content is 0.60% or more, the strength of the base metal is excessively increased, and thus low temperature toughness is reduced. Therefore, the Cu content is less than 0.60%. The upper limit of the Cu content is preferably 0.50%.

(Ni: 0.01% or more and less than 0.50%)

[0021] Ni is a very effective element in increasing the strength and the toughness of the base metal. Particularly, in order to increase the toughness, in the H-section steel according to this embodiment, the lower limit of the Ni content is 0.01 %. A preferable lower limit of the Ni content is 0.20%. On the other hand, increasing the Ni content to 0.50% or more causes an increase in alloy cost. Therefore, the Ni content is less than 0.50%. The upper limit of the Ni content is preferably 0.40%.

(Ti: 0.001% to 0.025%)

[0022] Ti is an important element to the enhancement of the toughness of the base metal. Ti forms fine Ti-containing oxides or TiN, and thus contributes to the refinement of the grain size. In order to obtain this effect, the lower limit of the Ti content is 0.001%. Furthermore, in a case where the hardenability is increased by fixing N with Ti and thus ensuring solid solution B, the lower limit of the Ti content is preferably 0.010%. On the other hand, when the Ti content is more than 0.025%, coarse TiN is generated, and thus the toughness of the base metal is reduced. Therefore, the upper limit of the Ti content is 0.025%. In addition, in order to suppress the precipitation of TiC and further suppress a reduction in toughness through precipitation hardening, the upper limit of the Ti content is preferably 0.020%.

(Nb: 0.010% to 0.070%)

[0023] Nb is an element which increases the hardenability of steel. In order to obtain this effect, the lower limit of the Nb content is 0.010%. In order to further enhance the strength and the toughness of the base metal, the lower limit of the Nb content is preferably 0.020%. On the other hand, when the Nb content is more than 0.070%, Nb carbonitride precipitates and thus the toughness of the base metal and the HAZ may be reduced. Therefore, the upper limit of the Nb content is 0.070%. In order to further increase the toughness, the upper limit of the Nb content is preferably 0.060%, and is more preferably 0.040%.

(N: 0.001 % to 0.009%)

[0024] N is bonded to fine Ti, forms TiN, and thus has an effect of refining grains. In order to obtain this effect, the lower limit of the N content is 0.001%. On the other hand, when the N content is more than 0.009%, coarse TiN is generated, and thus the toughness is reduced. Therefore, the upper limit of the N content is 0.009%. In addition, when the N content is increased, martensite-island is generated, and thus the toughness may be deteriorated. Therefore, the upper limit of the N content is preferably 0.005%.

(O: 0.0005% to 0.0035%)

[0025] O is an impurity, and in order to ensure the toughness by suppressing the generation of oxides, the upper limit of the O content is 0.0035%. In order to enhance the HAZ toughness, the upper limit of the O content is preferably

0.0015%. From the viewpoint of toughness, the O content is preferably as low as possible. However, when the O content is to be less than 0.0005%, the manufacturing cost is increased. Therefore, the lower limit of the O content may be 0.0005%. In addition, in a case of suppressing the coarsening of the grain size of HAZ by using a pinning effect caused by oxides, the lower limit of the O content may be 0.0008%.

(Al: more than 0.005% and 0.040% or less)

[0026] Al is a deoxidizing element. In order to obtain this effect, the Al content is more than 0.005%. On the other hand, in order to prevent the generation of coarse oxides, the upper limit of the Al content is 0.040%. In addition, a reduction in the Al content is also effective in suppressing the generation of the martensite-island. Therefore, the upper limit of the Al content is preferably 0.020%, and is more preferably 0.010%.

(B: more than 0.0003% and 0.0015% or less)

[0027] B is an element which increases the hardenability of steel with a small amount of B and thus accelerates the formation of fine bainite structures that are effective in toughness enhancement. In order to obtain this effect, the B content is more than 0.0003%. Here, when the B content is more than 0.0015%, although the bainite structures can be sufficiently obtained, martensite-island is also generated. In this case, the strength is increased too much, resulting in a significant reduction in the toughness. Therefore, the upper limit of the B content is 0.0015%. The preferable upper limit of the B content is 0.0010%.

(Nb content and B content satisfy $Nb+125\times B\geq 0.075\%$ in terms of mass %)

[0028] By allowing the Nb content and the B content to be in appropriate ranges, it is possible to ensure the strength even when the C content is reduced. As a result, the generation of carbide such as cementite, which is the origin of fracture, is suppressed and thus the toughness is enhanced. In a case where $Nb+125\times B$ is less than 0.075%, sufficient hardenability cannot be obtained, and the toughness of the base metal and the heat affected zone is reduced. In the H-section steel according to this embodiment in which the C content is reduced, $Nb+125\times B$ is preferably as high as possible, and the upper limit thereof is not specified. However, according to the upper limits of the Nb content and the B content, the upper limit of $Nb+125\times B$ is practically 0.2575%.

[0029] The amounts of P and S which are contained as impurities are not particularly limited. In addition, P and S cause weld cracking and a reduction in toughness due to solidifying segregation, and thus need to be reduced as much as possible. The P content is preferably limited to 0.02% or less, and is more preferably limited to 0.002% or less. In addition, the S content is preferably limited to 0.002% or less.

[0030] The H-section steel according to this embodiment basically contains the above-described chemical composition and may further contain one or two or more types of V, Mo, Cr, Zr, Hf, REM, and Ca for the purpose of enhancing strength and toughness or controlling the forms of inclusions. In addition, such elements do not need to be necessarily contained, and the lower limits of the amounts thereof are 0%.

(V: 0.10% or less)

[0031] V contributes to the refinement of structures and precipitation strengthening due to carbonitride. In a case of obtaining this effect, the lower limit of the V content is desirably 0.01%. However, when the V content is excessive, the toughness of the base metal and the HAZ may be reduced. Therefore, the upper limit of the V content is preferably 0.10%.

(Mo: 0.10% or less)

[0032] Mo is an element which is dissolved in steel, increases the hardenability of the steel, and thus contributes to strength enhancement. In a case of obtaining this effect, the lower limit of the Mo content is preferably 0.01%. However, when the Mo content is more than 0.10%, Mo carbide (Mo_2C) precipitates, and thus an effect of enhancing the hardenability due to the dissolved Mo reaches the upper limit. Moreover, the heat affected zone is hardened, and thus the HAZ toughness is deteriorated. Therefore, the upper limit of the Mo content is 0.10%. A more preferable upper limit of the Mo content is 0.05%.

(Cr: less than 0.20%)

[0033] Cr is an element which increases the hardenability of steel and thus contributes to strength enhancement. In a case of obtaining this effect, the lower limit of the Cr content is desirably 0.01%. However, when the Cr content is

0.20% or more, carbide is generated and thus the toughness may be reduced. Therefore, the Cr content is preferably less than 0.20%. A preferable upper limit of the Cr content is 0.10%.

(Zr: 0.030% or less and Hf: 0.010% or less)

[0034] Both Zr and Hf are deoxidizing elements, are elements which generate nitride at a high temperature, and are effective elements in reducing the amount of N dissolved in steel. In a case of obtaining this effect, the lower limit of the amount of any of the elements is desirably 0.001%. However, when Zr and Hf are excessively contained, nitride is coarsened and thus the toughness may be reduced. Therefore, it is preferable that the upper limit of the Zr content is 0.030% and the upper limit of the Hf content is 0.010%.

(REM: 0.010% or less and Ca: 0.0050% or less)

[0035] Both REM and Ca are deoxidizing elements, and elements which contribute to the control of the forms of sulfide. Therefore, in a case of obtaining this effect, the lower limit of the content is preferably 0.0001%. However, oxides of REM and Ca easily float in molten steel, and thus practically, the upper limits of the REM content and the Ca content which are contained in steel are respectively 0.010% and 0.0050%. In addition, REM is the abbreviation for Rare Earth Metal, and indicates 17 types of elements including Sc and Y in addition to lanthanides.

[0036] Next, the metallographic structure of the H-section steel according to this embodiment will be described.

[0037] The metallographic structure of the H-section steel according to this embodiment is a structure mainly including fine grains of ferrite and bainite excellent in strength and toughness and has a limited fraction of pearlite.

[0038] (Distribution density of pearlite in metallographic structure of cross-section perpendicular to rolling direction in thickness center portion and 1/4 flange width portion of flange is 3.2×10^{-3} units/μm^2 or lower and remainder practically contains ferrite and bainite.)

[0039] In the H-section steel according to this embodiment, in particular, there is concern that pearlite in the base metal may be transformed into martensite-island after welding and may deteriorate the toughness of a heat affected zone. Here, the metallographic structure of the H-section steel according to this embodiment is a structure in which the distribution density of pearlite is 3.2×10^{-3} units/μm^2 or lower and the remainder practically contains ferrite and bainite.

[0040] When the distribution density of pearlite is higher than 3.2×10^{-3} units/μm^2, pearlite is decomposed into austenite due to the weld heat input during welding, and after cooling, martensite-island is generated. The generated martensite-island may act as the origin of brittle fracture and may deteriorate toughness.

[0041] It is preferable that the distribution density of pearlite is as low as possible. However, from the viewpoint of ensuring strength, the lower limit of the distribution density of pearlite may be 1.0×10^{-5} units/μm^2.

[0042] The distribution density of pearlite is obtained by observing pearlite colonies (islands of pearlite in the JIS specification) in the above site with an optical microscope on the basis of JIS G 0551. Specifically, the number of pearlite colonies that are present in an optical micrograph often visual fields (the size of one visual field is preferably 120 $\mu m\times160$ μm) taken under 500 power magnification is counted, and the distribution density thereof is obtained.

[0043] In the case of the H-section steel according to this embodiment, the properties of the flange are important, and the observation of the metallographic structure and the measurement of the pearlite distribution density are performed on the thickness center portion and 1/4 flange width portion of the flange which is considered as a good representative of the entire structure in the cross-section perpendicular to the rolling direction of the H-section steel. That is, a sample is collected from the (1/4)F position of the cross-section of the H-section steel shown in FIG. 1 (the center portion of a thickness t_2 of the flange of the cross-section perpendicular to the rolling direction: $(1/2)t_2$ and 1/4 of the entire length B of the flange width: (1/4)B). Ferrite, bainite, and pearlite are distinguished from each other using an optical microscope, the number of pearlite colonies is measured, and then the distribution density thereof is obtained.

(Thickness of flange is 12 mm to 40 mm)

[0044] The thickness of the flange of the H-section steel according to this embodiment is 12 mm to 40 mm. This is because H-section steel having a thickness of 12 mm to 40 mm is widely used as the H-section steel used in a structure used in cold regions (a low temperature structure). In addition, when the thickness of the flange is greater than 40 mm, the cooling rate is reduced and thus the distribution density of pearlite may be increased.

[0045] The thickness of a web is preferably 12 mm to 40 mm similar to that of the flange.

[0046] Assuming that the H-section steel is produced by hot rolling, the ratio (flange/web) of the flange thickness to the web thickness is preferably 0.5 to 2.0. When the flange/web ratio is higher than 2.0, the web may be deformed into a wavy shape. On the other hand, in a case where the flange/web ratio is lower than 0.5, the flange may be deformed into a wavy shape.

[0047] Regarding the strength of the H-section steel according to this embodiment, it is preferable that the yield point or the 0.2% proof stress at room temperature is 345 MPa or higher and the tensile strength is 460 MPa to 550 MPa. In addition, the Charpy impact absorbed energy of the base metal portion at -40°C is preferably 60 J or higher. Furthermore, in order to reasonably guarantee the low temperature toughness, it is preferable that the CTOD value at -10°C is 0.25 mm or higher. In addition, it is preferable that the Charpy impact absorbed energy and the CTOD value of the heat affected zone are equal to or higher than those of the base metal portion.

[0048] It is difficult for the H-section steel to ensure strength and toughness compared to a case of producing a steel plate. The reason is that when an ultra thick H-section steel is produced from a material having a slab shape or a beam blank shape, it is difficult to ensure the work amount of a flange and a fillet portion (a portion where the flange and the web are joined together).

[0049] Next, a preferable method of producing the H-section steel according to this embodiment will be described.

[0050] In a steel production process, the chemical composition of molten steel is adjusted to be in the above-described ranges by an arbitrary method, and the molten steel is cast to obtain a steel slab. As the casing, continuous casting is preferable from the viewpoint of productivity. In addition, the thickness of the steel slab is preferably 200 mm or greater from the viewpoint of productivity. On the other hand, in consideration of a reduction in the degree of segregation, homogeneity of heating temperature during hot rolling, and the like, the thickness of the steel slab is preferably 350 mm or smaller.

[0051] Subsequently, the steel slab is heated (heating process: S1), and hot rolling is performed on the heated steel slab (hot rolling process). The heating temperature of the steel slab is preferably 1100°C to 1350°C. When the heating temperature is lower than 1100°C, deformation resistance is increased. Therefore, the lower limit of the heating temperature is preferably 1100°C. In order to sufficiently dissolve elements which form carbides and nitrides, such as Nb, the lower limit of the heating temperature is more preferably 1150°C. Particularly, in a case where the thickness of the flange is small, there is concern that cumulative rolling reduction may be increased and thus the rolling temperature may be reduced too much. Therefore, it is more preferable that the heating is performed at 1200°C or higher. On the other hand, when the heating temperature is higher than 1350°C, a scale on the surface of the steel slab which is a material is liquefied and thus the inside of a heating furnace may be damaged. Therefore, the upper limit of the heating temperature is preferably 1350°C. In order to suppress coarsening of the structure, the upper limit of the heating temperature is more preferably 1300°C.

[0052] Hot rolling is performed subsequent to the heating process (hot rolling process: S2). In the hot rolling process, the rolling is performed by sequentially rolling the steel slab through a universal rolling apparatus line including a roughing mill, an intermediate rolling mill, and a finishing mill. In the roughing mill, the steel slab extracted from the heating furnace is rolled into a predetermined size (rough rolling process: S21). Thereafter, intermediate rolling is performed by the intermediate rolling mill (intermediate rolling process: S22). During the intermediate rolling, controlled rolling in which rolling temperature and rolling reduction are controlled is performed. As a method of the controlled rolling, for example, when the rolling is performed in two or more passes by reverse rolling, the flange outer surface is water-cooled by cooling apparatuses which are disposed in the front and the rear of the reverse rolling, and the temperature of the flange outer surface is recuperated and the flange is rolled. During the water cooling, when the temperature of the flange outer surface is reduced too much, the recuperating is delayed until the rolling is performed, and thus spray cooling is preferable.

[0053] After the intermediate rolling process, finish rolling is performed (finish rolling process: S23). During the finish rolling, the rolling needs to be performed in one or more passes while the surface temperature of the flange is 770°C to 870°C. The reason why the above-described rolling is performed is that work recrystallization is accelerated during the hot rolling (finish rolling) and thus austenite is refined such that toughness and strength are enhanced. When the surface temperature of the flange is lower than 770°C, shaping of the H-section steel is difficult, and thus the lower limit thereof is 770°C. On the other hand, when the surface temperature of the flange is higher than 870°C, strain is recovered, recrystallized grains grow and become coarsened, and thus the upper limit thereof is 870°C. The upper limit of the number of passes of the rolling is not limited. However, when the rolling is performed in more than five passes at a surface temperature of 770°C to 870°C, the amount of strain per one pass is reduced and thus the effect of refining the grains may be reduced. Therefore, the number of passes is preferably five or less.

[0054] During the finish rolling, interpass water cooling rolling is preferably performed in one or more passes. The interpass water cooling rolling is a method of cooling the surface temperature of the flange to 700°C or less and thereafter performing the rolling in the recuperating process. During the interpass water cooling rolling, a temperature difference occurs between the surface layer portion and the inner portion of the flange due to the water cooling between the rolling passes. Therefore, during the interpass water cooling rolling, even in a case where the rolling reduction is small, work strain can be introduced to the thickness inner portion. In addition, the rolling temperature can be reduced by water cooling done within a short period of time, and thus productivity is enhanced.

[0055] After the finish rolling, air cooling is performed according to a general method (air cooling process: S3). Due to the air cooling, the structure of the H-section steel becomes a structure in which pearlite is partially generated and essentially consisting of ferrite and bainite.

[0056] During the air cooling, the average temperature of the flange may be cooled to 400°C or less and thereafter be recuperated to a temperature range of 400°C to 500°C. When the average temperature is recuperated to 400°C to 500°C, martensite-island which is present in the microstructure in the rolled state can be decomposed. In order to allow C in the martensite-island to be diffused in a matrix, it is preferable that the heating temperature is 400°C or higher and the holding time is 15 minutes or longer. The upper limit of the heating temperature and the upper limit of the holding time are not particularly specified. However, from the viewpoint of manufacturing cost, it is preferable that the heating temperature is 500°C or lower and the holding time is 5 hours or shorter. The recuperating of the temperature done after the cooling may be performed in a heat treatment furnace.

[0057] FIG. 2 shows a flowchart of an example of the production method.

[0058] In addition, a production process of performing primary rolling, and performing cooling to 500°C or lower, thereafter performing heating to 1100°C to 1350°C, and performing secondary rolling, that is a so-called two heat rolling may also be employed. During the two heat rolling, the amount of plastic deformation is small during the hot rolling, a reduction in temperature during the rolling process is also reduced, and thus the heating temperature can also be reduced.

[Examples]

[0059] Hereinafter, the present invention will be described in detail on the basis of Examples.

[0060] Steels having the component compositions shown in Table 1 were melted and were subjected to continuous casting such that steel slabs having thicknesses of 240 mm to 300 mm were produced. The melting of the steel was performed in a converter, primary deoxidation was performed, and alloys were added to adjust the components. As necessary, vacuum degassing was performed. The obtained steel slabs were heated and were subjected to hot rolling, thereby producing H-section steels. The components shown in Table 1 were obtained by chemical analysis of samples collected from the produced H-section steels. In addition, the remainder in Table 1 contains Fe and an impurity.

[Table 1]

STEEL No.	COMPOSITION (mass%)																	Nb+125 × B	NOTE
	C	Si	Mn	Cu	Ni	Al	Ti	Nb	N	O	B	V	Mo	Cr	Zr	Hf	Ca	REM		
A	0.014	0.20	1.82	0.01	0.01	0.016	0.020	0.040	0.0042	0.0009	0.0004								0.090	INVENTION EXAMPLE
B	0.014	0.20	1.65	0.01	0.01	0.007	0.020	0.040	0.0036	0.0024	0.0004		0.05						0.090	
C	0.014	0.20	1.65	0.01	0.01	0.016	0.020	0.040	0.0040	0.0010	0.0004								0.090	
D	0.014	0.06	1.98	0.01	0.01	0.020	0.021	0.040	0.0041	0.0030	0.0005								0.103	
E	0.013	0.46	0.81	0.01	0.01	0.010	0.019	0.040	0.0041	0.0009	0.0004								0.090	
F	0.014	0.20	0.84	0.01	0.01	0.016	0.020	0.050	0.0038	0.0010	0.0005								0.113	
G	0.013	0.21	0.83	0.57	0.01	0.015	0.021	0.030	0.0040	0.0011	0.0004								0.080	
H	0.012	0.20	0.83	0.01	0.30	0.016	0.020	0.040	0.0040	0.0010	0.0004								0.090	
I	0.011	0.20	0.82	0.26	0.35	0.016	0.020	0.040	0.0039	0.0010	0.0004								0.090	
J	0.014	0.28	1.85	0.01	0.01	0.008	0.024	0.050	0.0030	0.0028	0.0005								0.113	
K	0.014	0.14	1.70	0.01	0.01	0.037	0.015	0.040	0.0025	0.0009	0.0004								0.090	
L	0.013	0.23	0.86	0.02	0.01	0.017	0.003	0.040	0.0044	0.0025	0.0005								0.103	
M	0.014	0.20	0.80	0.01	0.01	0.015	0.024	0.040	0.0039	0.0009	0.0004								0.090	
N	0.014	0.24	1.90	0.01	0.01	0.016	0.020	0.020	0.0043	0.0010	0.0005								0.083	
O	0.012	0.19	1.80	0.05	0.01	0.015	0.019	0.070	0.0040	0.0009	0.0004								0.120	
P	0.014	0.20	1.86	0.01	0.01	0.015	0.019	0.040	0.0014	0.0010	0.0004								0.090	
Q	0.013	0.20	1.82	0.01	0.01	0.020	0.025	0.030	0.0080	0.0009	0.0005								0.093	
R	0.014	0.19	1.80	0.01	0.01	0.014	0.019	0.040	0.0045	0.0005	0.0004								0.090	
S	0.012	0.22	1.92	0.01	0.01	0.026	0.025	0.040	0.0030	0.0030	0.0005								0.103	
T	0.012	0.19	1.81	0.02	0.01	0.015	0.020	0.030	0.0070	0.0029	0.0013								0.193	
U	0.012	0.20	1.78	0.01	0.01	0.015	0.020	0.020	0.0034	0.0009	0.0005	0.06							0.083	
V	0.011	0.20	1.65	0.01	0.05	0.015	0.020	0.030	0.0039	0.0009	0.0004		0.08						0.080	
W	0.014	0.20	1.82	0.01	0.01	0.016	0.020	0.040	0.0042	0.0009	0.0004			0.18					0.090	
X	0.014	0.19	1.80	0.01	0.01	0.014	0.013	0.040	0.0044	0.0010	0.0004				0.02				0.090	
Y	0.013	0.19	1.80	0.01	0.01	0.014	0.013	0.040	0.0044	0.0009	0.0004					0.006			0.090	
Z	0.014	0.19	1.81	0.01	0.01	0.014	0.013	0.040	0.0039	0.0009	0.0004							0.007	0.090	
AA	0.014	0.19	1.80	0.01	0.01	0.014	0.013	0.040	0.0044	0.0009	0.0004						0.003		0.090	
AB	0.011	0.19	1.80	0.01	0.20	0.014	0.020	0.040	0.0039	0.0009	0.0004	0.03	0.03						0.090	
AC	0.014	0.20	1.82	0.01	0.01	0.006	0.020	0.040	0.0042	0.0009	0.0004								0.090	
AD	0.017	0.48	1.82	0.01	0.01	0.016	0.020	0.040	0.0041	0.0009	0.0004								0.090	COMPARATIVE EXAMPLE
AE	0.016	0.08	1.85	0.01	0.01	0.015	0.021	0.040	0.0040	0.0010	0.0005								0.103	
AF	0.012	0.20	1.82	0.01	0.01	0.016	0.020	0.030	0.0042	0.0010	0.0002								0.055	
AG	0.014	0.52	1.82	0.01	0.01	0.016	0.020	0.040	0.0042	0.0009	0.0004								0.090	
AH	0.014	0.20	2.10	0.01	0.01	0.016	0.020	0.040	0.0041	0.0009	0.0004								0.090	
AI	0.014	0.19	0.70	0.01	0.01	0.016	0.020	0.041	0.0042	0.0010	0.0004								0.091	
AJ	0.013	0.20	1.82	0.70	0.01	0.016	0.019	0.040	0.0042	0.0009	0.0005								0.103	
AK	0.014	0.20	1.82	0	0.01	0.016	0.020	0.040	0.0042	0.0009	0.0004								0.090	
AL	0.014	0.20	1.82	0.01	0	0.015	0.020	0.039	0.0040	0.0009	0.0004								0.089	
AM	0.013	0.19	1.82	0.01	0.01	0.050	0.020	0.040	0.0042	0.0010	0.0004								0.090	
AO	0.014	0.20	1.82	0.01	0.01	0.017	0.020	0.040	0.0042	0.0009	0.0017								0.253	
AP	0.014	0.19	1.85	0.01	0.01	0.016	0.020	0.080	0.0042	0.0009	0.0004								0.130	
AQ	0.014	0.20	1.82	0.01	0.01	0.016	0.020	0.040	0.0105	0.0009	0.0004								0.090	
AR	0.014	0.20	1.82	0.01	0.01	0.015	0.020	0.040	0.0009	0.0009	0.0004								0.090	
AS	0.012	0.20	1.82	0.01	0.01	0.016	0.020	0.020	0.0042	0.0010	0.0004								0.070	
AT	0.014	0.20	1.82	0.01	0.01	0.004	0.020	0.040	0.0042	0.0009	0.0004								0.090	
AU	0.012	0.20	1.82	0.01	0.01	0.016	0.020	0.060	0.0042	0.0010	0.0003								0.098	

BLANK REPRESENTS THAT INTENTIONALLY NO ELEMENT IS ADDED.
UNDERLINE REPRESENTS OUT OF THE RANGE OF THE PRESENT INVENTION.

[0061] The process of producing the H-section steel is shown in FIG. 2 and a production apparatus used in the heating process and the hot rolling process is shown in FIG. 3. The hot rolling was performed by the universal rolling apparatus line. In a case where the interpass water cooling rolling was performed as the hot rolling, as the water cooling between the rolling passes, controlled cooling in which reverse rolling was performed while spray cooling was performed on the flange outer surface by using water cooling apparatuses 3a provided in the front and rear of an intermediate universal rolling mill 2b was performed. After the hot rolling, air cooling was performed. The production conditions are shown in Table 2.

[Table 2]

PRODUCTION No.	STEEL No.	HEATING TEMPERATURE (°C)	FINISH ROLLING TEMPERATURE (°C)	NUMBER OF PASSES AT 770°C TO 870°C	FLANGE THICKNESS (mm)	NOTE
1	A	1300	870	1	40	EXAMPLE
2	B	1300	850	3	25	
3	C	1300	850	3	25	
4	D	1300	850	3	25	
5	E	1300	850	3	25	
6	F	1300	850	3	25	
7	G	1300	850	3	25	
8	H	1300	850	3	25	
9	I	1300	850	3	25	
10	J	1300	850	3	25	
11	K	1300	850	3	25	
12	L	1300	850	3	25	
13	M	1300	850	3	25	
14	N	1300	850	3	25	
15	O	1300	850	3	25	
16	P	1300	850	3	25	
17	Q	1300	850	3	25	
18	R	1300	850	3	25	
19	S	1300	850	3	25	
20	T	1300	850	3	25	
21	U	1300	850	3	25	
22	V	1300	850	3	25	
23	W	1300	850	3	25	
24	X	1300	850	3	25	
25	Y	1300	850	3	25	
26	Z	1300	850	3	25	
27	AA	1300	850	3	25	
28	AB	1300	850	3	25	
29	AC	1300	870	1	40	
30	A	1300	790	5	12	

(continued)

PRODUCTION No.	STEEL No.	HEATING TEMPERATURE (°C)	FINISH ROLLING TEMPERATURE (°C)	NUMBER OF PASSES AT 770°C TO 870°C	FLANGE THICKNESS (mm)	NOTE
31	AD	1300	850	3	25	COMPARATIVE EXAMPLE
32	AE	1300	850	1	40	
33	AF	1300	850	3	25	
34	AG	1300	870	1	40	
35	AH	1300	870	1	40	
36	AI	1300	870	1	40	
37	AJ	1300	870	1	40	
38	AK	1300	870	1	40	
39	AL	1300	870	1	40	
40	AM	1300	870	1	40	
41	AO	1300	870	1	40	
42	AP	1300	870	1	40	
43	AQ	1300	870	1	40	
44	AR	1300	870	1	40	
45	AS	1300	870	1	40	
46	AT	1300	870	1	40	
47	AU	1300	870	1	40	
48	F	1300	870	1	50	

[0062] As shown in FIG. 1, a test piece was collected from the center portion ($(1/2)t_2$) of the thickness t_2 of a flange 5 of an H-section steel 4 at the 1/4 ((1/4)B position ((1/4)F of FIG. 1) of the entire length (B) of the flange width, and the mechanical properties thereof were measured. The reason why the evaluation was performed on this point is that it was determined that the flange (1/4)F portion of FIG. 1 showed the average mechanical properties of the H-section steel. A tensile test was performed on the basis of JIS Z 2241, and a Charpy impact test was performed on the basis of JIS Z 2242 at -40°C. As a CTOD test piece, the entire thickness of the flange portion was cut out and a smooth test piece was produced. A notch position was set to be on the extension line of the original web surface.

[0063] The obtained flange portion of the base metal was cut out and a single bevel groove was provided to be used as a sample for performing welding. Gas metal arc welding was performed on the sample with a weld heat input of 12 kJ/cm. A test piece was collected so that to allow a Charpy impact test piece or a CTOD test piece notch is formed at a position of 2 mm from a fusion line (the boundary line between the welded metal and the base metal) on the vertical portion side of the groove, and the toughness of the heat affected zone was evaluated.

[0064] In addition, a sample was collected from the position where the test piece used for measuring the mechanical properties was collected, the metallographic structure of this sample was observed with an optical microscope, and the distribution density of pearlite was measured. It was confirmed that the remainder excluding pearlite was ferrite and bainite.

[0065] The results are shown in Table 3. As the target values of the mechanical properties, the yield point or 0.2% proof stress at room temperature is 345 MPa or higher, the tensile strength is 460 MPa to 550 MPa, and the Charpy impact absorbed energy of both of the base metal and the HAZ at -40°C is 60 J or higher, and the CTOD value at -10°C is 0.25 mm or higher. As shown in Table 4, in all of Production Nos. 1 to 30, the 0.2% proof stress at room temperature, the tensile strength, the Charpy impact absorbed energy at -40°C, and the CTOD value at -10°C of both of the base metal and the heat affected zone sufficiently satisfy the target values.

[0066] On the other hand, Production No. 31 is an example in which the C content is excessive and the toughness of the heat affected zone is reduced. Production No. 32 is also an example in which the C content is excessive, the fraction of pearlite is excessive, and the toughness of the heat affected zone is reduced. Production No. 33 is an example in which the B content and the value of Nb+125×B are excessively low, appropriate hardenability cannot be obtained, and thus the toughness of the base metal and the heat affected zone is reduced. Production No. 34 is an example in which the Si content is excessive, the fraction of pearlite is excessive, and thus the toughness of the heat affected zone is reduced. Production No. 35 is an example in which the Mn content is excessive, the fraction of pearlite is excessive, and thus the toughness of the heat affected zone is reduced. Production No. 36 is an example in which the Mn content is excessively low, and the strength of the base metal was not sufficiently obtained. Production No. 37 is an example in which the Cu content is excessive, the strength of the base metal is excessively high, and thus the toughness of the base metal and the heat affected zone is reduced. Production No. 38 is an example in which Cu is not contained and the strength of the base metal was not sufficiently obtained. Production No. 39 is an example in which Ni is not contained and the toughness of the base metal and the heat affected zone is reduced. Production No. 40 is an example in which the Al content is excessive and the toughness of the base metal and the heat affected zone is reduced. Production No. 41 is an example in which the B content is excessive, the strength of the base metal is excessively large, and the toughness of the base metal and the heat affected zone is reduced. Production No. 42 is an example in which the Nb content is excessive, the strength of the base metal is excessively large, and the toughness of the base metal and the heat affected zone is reduced. Production No. 43 is an example in which the N content is excessive and the toughness of the base metal and the heat affected zone is reduced. Production No. 44 is an example in which the N content is excessively low and the toughness of the base metal and the heat affected zone is reduced. Production No. 45 is an example in which Expression 1 is not satisfied and the toughness of the base metal and the heat affected zone is reduced. Production No. 46 is an example in which the Al content is excessively low and the toughness of the base metal and the heat affected zone is reduced. Production No. 47 is an example in which the B content is low and the toughness of the base metal and the heat affected zone is reduced. Production No. 48 is an example in which the thickness is too large, the fraction of pearlite is excessive, and the toughness of the base metal and the heat affected zone is reduced.

[Table 3]

PRODUCTION No.	STEEL No.	DISTRIBUTION DENSITY OF PEARLITE ($10^{-3}/\mu m^2$)	BASE METAL YS (MPa)	BASE METAL TS (MPa)	BASE METAL vE_{-40} (J)	HAZ PORTION vE_{-40} (J)	BASE METAL CTOD VALUE (mm)	HAZ CTOD VALUE (mm)	NOTE
1	A	2.3	409	517	393	300	0.51	0.37	EXAMPLE
2	B	2.4	421	518	391	63	0.50	0.27	
3	C	2.9	405	514	395	63	0.52	0.28	
4	D	2.4	444	549	350	62	0.30	0.27	
5	E	2.1	346	461	399	321	0.55	0.41	
6	F	3.0	402	511	389	63	0.49	0.27	
7	G	2.0	347	462	398	322	0.51	0.40	
8	H	1.9	422	520	392	331	0.50	0.41	
9	I	1.8	423	521	390	301	0.49	0.39	
10	J	2.2	514	530	298	298	0.34	0.34	
11	K	2.8	385	488	390	61	0.44	0.26	
12	L	2.2	346	461	395	304	0.50	0.36	
13	M	2.5	346	466	396	289	0.59	0.41	
14	N	3.0	403	512	390	62	0.50	0.28	
15	O	1.9	403	510	393	351	0.56	0.48	
16	P	2.4	419	531	297	287	0.28	0.28	
17	Q	2.1	410	515	392	320	0.47	0.35	
18	R	2.5	405	516	393	289	0.53	0.35	
19	S	2.3	430	543	285	295	0.41	0.40	
20	T	1.9	405	514	394	342	0.40	0.30	
21	U	1.9	413	529	274	76	0.28	0.26	
22	V	1.7	422	512	320	82	0.40	0.30	
23	W	2.2	422	541	385	104	0.44	0.26	

(continued)

PRODUCTION No.	STEEL No.	DISTRIBUTION DENSITY OF PEARLITE ($10^{-3}/\mu m^2$)	BASE METAL YS (MPa)	BASE METAL TS (MPa)	BASE METAL vE_{-40} (J)	HAZ PORTION vE_{-40} (J)	BASE METAL CTOD VALUE (mm)	HAZ CTOD VALUE (mm)	NOTE
24	X	2.0	409	515	396	277	0.44	0.30	
25	Y	2.1	418	518	291	301	0.35	0.35	
26	Z	2.2	407	514	395	293	0.39	0.26	
27	AA	2.2	406	519	285	299	0.39	0.37	
28	AB	1.7	421	511	311	81	0.39	0.29	
29	AC	2.4	420	510	392	64	0.51	0.26	
30	A	2.1	418	521	394	283	0.25	0.45	
31	AD	3.0	403	511	380	37	0.49	0.10	COMPARATIVE EXAMPLE
32	AE	3.4	401	510	381	36	0.48	0.11	
33	AF	3.1	401	509	55	37	0.21	0.10	
34	AG	3.4	401	510	381	36	0.48	0.11	
35	AH	3.4	401	510	381	36	0.48	0.11	
36	AI	3.1	403	455	72	65	0.26	0.26	
37	AJ	3.1	410	559	45	41	0.20	0.19	
38	AK	3.1	349	455	124	120	0.29	0.28	
39	AL	3.0	356	463	41	40	0.19	0.22	
40	AM	3.0	420	510	55	49	0.10	0.09	
41	AO	2.9	412	552	52	48	0.09	0.08	
42	AP	2.9	379	580	50	46	0.21	0.20	
43	AQ	2.9	421	511	49	31	0.20	0.19	
44	AR	2.9	401	510	49	58	0.21	0.21	
45	AS	3.1	401	509	55	37	0.21	0.10	
46	AT	3.1	401	508	55	37	0.22	0.11	

(continued)

PRODUCTION No.	STEEL No.	DISTRIBUTION DENSITY OF PEARLITE ($10^{-3}/\mu m^2$)	BASE METAL YS (MPa)	BASE METAL TS (MPa)	BASE METAL vE_{-40} (J)	HAZ PORTION vE_{-40} (J)	BASE METAL CTOD VALUE (mm)	HAZ CTOD VALUE (mm)	NOTE
47	AU	3.1	401	509	54	32	0.21	0.10	
48	F	3.3	367	496	56	35	0.19	0.10	

UNDERLINE REPRESENTS OUT OF THE RANGE OF THE PRESENT INVENTION.

[Industrial Applicability]

[0067] According to the present invention, the H-section steel for low temperature use having high strength and excellent low temperature toughness can be produced by rolling without performing accelerated cooling. As a result, a significant cost reduction due to a reduction in construction cost and a reduction in a construction period can be achieved. Furthermore, even when welding is performed on the H-section steel of the present invention, a reduction in the toughness of the heat affected zone is small. Therefore, the reliability of a large building used in cold regions can be enhanced without damage to economic efficiency. Therefore, the present invention makes a significant contribution to the industry.

[Brief Description of the Reference Symbols]

[0068]

1: heating furnace
2a: roughing mill
2b: intermediate rolling mill
2c: finishing mill
3a: cooling apparatuses on front and rear surfaces of intermediate rolling mill
4: H-section steel
5: flange
6: web
7: CTOD notch position of base metal
t_1 : thickness of web
t_2: thickness of flange
B: entire length of flange width
H: height

Claims

1. An H-section steel, wherein
a chemical composition thereof includes, in terms of mass%:

C: 0.010% to 0.014%;
Si: 0.05% to 0.50%;
Mn: 0.8% to 2.0%;
Cu: 0.01% or more and less than 0.60%;
Ni: 0.01 % or more and less than 0.50%;
Al: more than 0.005% and 0.040% or less;
Ti: 0.001% to 0.025%;
Nb: 0.010% to 0.070%;
N: 0.001% to 0.009%;
O: 0.0005% to 0.0035%;
B: more than 0.0003% and 0.0015% or less;
V: 0% to 0.10%;
Mo: 0% to 0.10%;
Cr: 0% or more and less than 0.20%;
Zr:0 to 0.030%;
Hf:0 to 0.010%;
REM:0 to 0.010%;
Ca:0 to 0.0050%; and
remainder including Fe and an impurity,
an Nb content and a B content satisfy Expression 1,
a thickness of a flange is 12 mm to 40 mm, and
in a thickness center portion and 1/4 flange width portion of the flange, a metallographic structure of a cross-section perpendicular to a rolling direction contains a pearlite having a distribution density of 3.2×10^{-3} units/μm^2 or lower and the remainder consists of a ferrite and a bainite,

$$Nb+125\times B\geq 0.075\% \quad \ldots\text{Expression 1,}$$

and where Nb and B in Expression 1 are amounts of the elements in terms of mass%.

2. The H-section steel according to claim 1,
wherein a tensile strength is 460 MPa to 550 MPa.

3. The H-section steel according to claim 1 or 2,
wherein the chemical composition includes, in terms of mass%, one or two or more types of:

V: 0.01% to 0.10%;
Mo: 0.01% to 0.10%; and
Cr: 0.01% or more and less than 0.20%.

4. The H-section steel according to any one of claims 1 to 3,
wherein the chemical composition includes, in terms of mass%, one or two types of:

Zr: 0.001% to 0.030%; and
Hf: 0.001% to 0.010%.

5. The H-section steel according to any one of claims 1 to 4,
wherein the chemical composition includes, in terms of mass%, one or two types of:

REM: 0.0001% to 0.010%; and
Ca: 0.0001% to 0.0050%.

6. A method of producing an H-section steel, the method comprising:

a heating process of heating a steel slab having the chemical composition according to any one of claims 1 to 5 to 1100°C to 1350°C;
a hot rolling process of performing a hot rolling on the steel slab into an H-section steel; and
an air cooling process of performing an air cooling on the H-section steel,
wherein the hot rolling process includes a rough rolling process of rolling the steel slab by using a roughing mill, an intermediate rolling process of performing a reverse rolling by using an intermediate rolling mill, and a finish rolling process of performing a rolling by using a finishing mill,
during the reverse rolling of the intermediate rolling process, a controlled rolling in which a rolling is performed while the H-section steel is cooled by using a water cooling apparatuses provided on a front surface and a rear surface of the intermediate rolling mill is performed,
in the finish rolling process, the rolling is performed in one or more passes while a surface temperature of a flange is in a range of 770°C to 870°C, and
a thickness of the flange is 12 mm to 40 mm.

FIG. 1

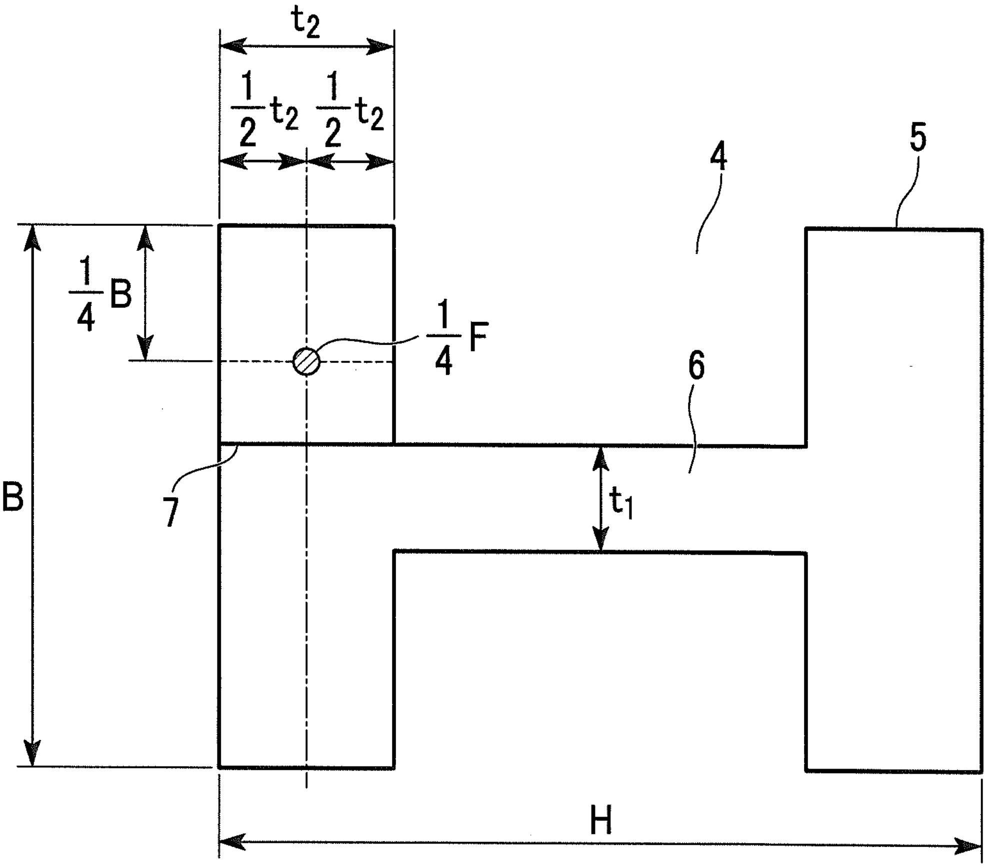


FIG. 2

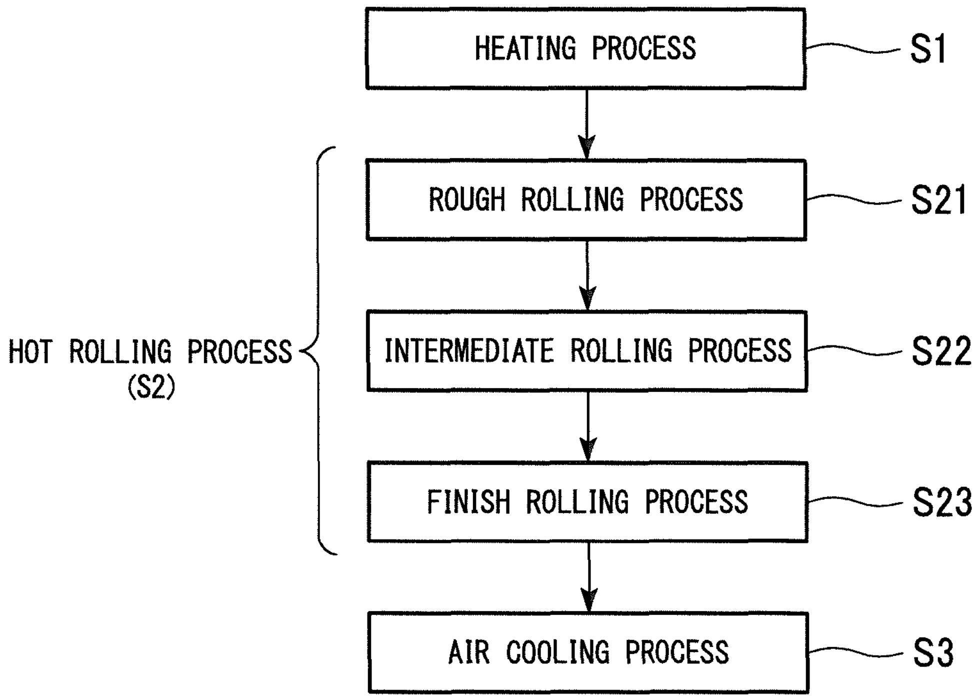
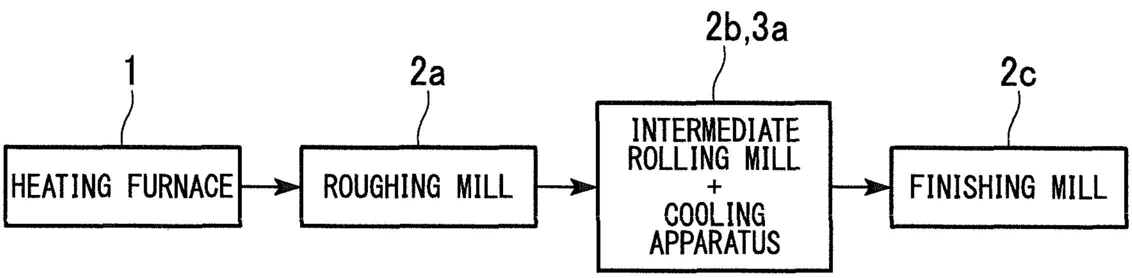

HEATING PROCESS
S1
ROUGH ROLLING PROCESS
S21
INTERMEDIATE ROLLING PROCESS
S22
FINISH ROLLING PROCESS
S23
AIR COOLING PROCESS
S3
HOT ROLLING PROCESS
(S2)

FIG. 3


1
HEATING FURNACE
2a
ROUGHING MILL
2b,3a
INTERMEDIATE
ROLLING MILL
+
COOLING
APPARATUS
2c
FINISHING MILL

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2014/060745

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C21D8/00*(2006.01)i, *C22C38/58*(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)
C22C38/00-38/60, C21D8/00-8/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2011/065479 A1 (Nippon Steel Corp.), 03 June 2011 (03.06.2011), claims & JP 4855553 B2	1-6
A	WO 2007/091725 A1 (Nippon Steel Corp.), 16 August 2007 (16.08.2007), claims & US 2009/0020190 A1 & EP 1983069 A1 & CN 101379209 A & KR 10-2008-0077240 A	1-6
A	JP 2008-121121 A (Nippon Steel Corp.), 29 May 2008 (29.05.2008), claims & WO 2008/029583 A1 & US 2010/0065168 A1 & EP 2065481 A1 & CN 101512033 A & KR 10-2009-0038033 A	1-6

☒ 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: 04 July, 2014 (04.07.14)	Date of mailing of the international search report: 15 July, 2014 (15.07.14)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2014/060745

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2001-9503 A (Kawasaki Steel Corp.), 16 January 2001 (16.01.2001), claims (Family: none)	1-6
A	CN 102676919 A (MAGANG GROUP HOLDING CO., LTD.), 19 September 2012 (19.09.2012), claims (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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- JP H11193440 B **[0007]**
- WO 200791725 PCT **[0007]**
- WO 2008126910 PCT **[0007]**
- JP 2011274278 A **[0007]**