

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
2 February 2006 (02.02.2006)

PCT

(10) International Publication Number
WO 2006/011618 A1

(51) International Patent Classification : **C22C 38/00**,
38/12, 38/26

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(21) International Application Number:
PCT/JP2005/013999

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(22) International Filing Date: 26 July 2005 (26.07.2005)

(25) Filing Language: English

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

(26) Publication Language: English

(30) Priority Data:
2004-220454 28 July 2004 (28.07.2004) JP
2004-220337 28 July 2004 (28.07.2004) JP
2005-207185 15 July 2005 (15.07.2005) JP

AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG,
KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,
MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM,
PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM,
SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN,
YU, ZA, ZM, ZW.

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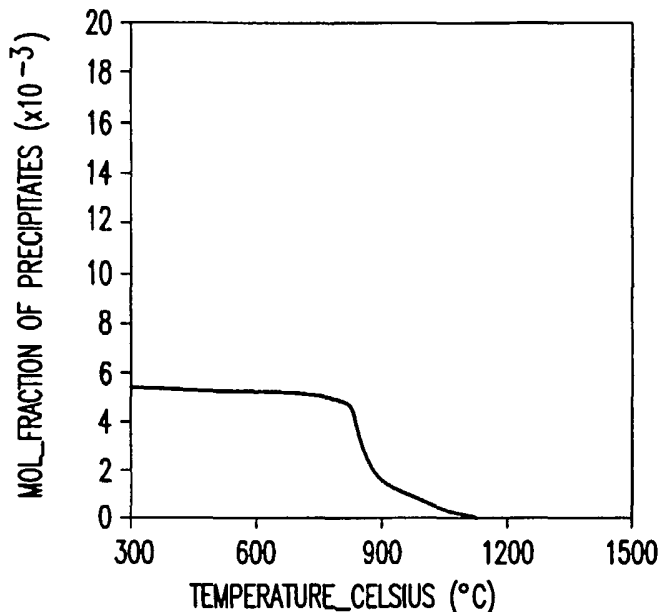
(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT,
RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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[Continued on next page]

(54) Title: SHAPED STEEL EXCELLENT IN FIRE RESISTANCE AND PRODUCING METHOD THEREFOR

COMPONENTS: 0.05C-0.15Si-0.7Mn-0.3Mo-0.35V-0.006Nb-0.004N
mol FRACTION OF PRECIPITATION OF (M₂C TYPE CARBIDE + MCN
TYPE CARBONITRIDE) AT 600°C: 0.53%
RATIO OF THE mol FRACTION AT 300°C TO THAT OF 600°C: 1.03



(57) Abstract: A shaped steel, such as H-shaped steel, excellent in fire resistance, where a flange portion has 50% or more of a ratio of strength, 80 % or less of yield ratio, and 100 J or more of impact strength of Charpy impact test at 0 °C, wherein the ratio of strength = (proof stress of 0.2% at 600°C)/(yield strength at room temperature), and a producing method thereof are provided. The shaped steel comprises in mass percent (%): C: 0.03-0.15; Mo: 0.1- 0.6; V ≤ 0.35; and N: 0.002-0.012, and the balance being iron and residual impurities, wherein (x) a mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C is 0.3 % or more, and (y) the ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300°C to the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C is 2.0 or less.

WO 2006/011618 A1



Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

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SHAPED STEEL EXCELLENT IN FIRE RESISTANCE AND
PRODUCING METHOD THEREFOR

[0001] This application claims priority to Japanese
10 patent application No. 2004-220337, filed in Japan on July 28,
2004, Japanese patent application No. 2004-220454, filed in
Japan on July 28, 2004, and Japanese patent application No.
2005-207185, filed in Japan on July 15, 2005, the entire
contents of which are herein incorporated by reference.

15 [0002] The present invention relates to a novel shaped
steel, such as H-shaped steel, I-shaped steel, angle steel,
channel steel, etc., which is used as a building construction
material, with a low yield ratio and having excellence in
toughness and fire resistance, and a method for producing the
20 same.

[0003] The legislation about "new code to design
fire-resistant structures" was enacted on March, 1987 in Japan.
After that, fire-resistant steel materials, which secure high
strength at high temperature without or with less
25 fire-resistant wrapping, have been desired.

[0004] As for shaped steels, according to the trend,

a lot of technologies for securing fire-resistance to steel were proposed. For example, it was proposed that strength, such as strength and yield ratio, at high temperature, such as 600°C, was secured by employing technologies of precipitation
5 strengthening using Mo-based carbides.

[0005] For example, Japanese laid open No. 9-104944 proposes a fire-resistant shaped steel using precipitation strengthening technology and oxide metallurgy technology. Oxide metallurgy technology is a technology, which can control
10 the number of oxides, which oxides are obtained by deoxidization of the dissolved oxygen in steel using Ti, B and Mg. Oxide metallurgy technology provides the following effects.

[0006] In the production process of the shaped steel, different portions of the shaped steel are subjected
15 respectively to different temperatures of finish-rolling and to different cooling rates resulting from the unevenness of the shape on the section of the steel, which causes lack of uniformity the microstructure of the section of the steel. This lack of uniformity of the microstructure, such as
20 non-uniformity of grain size, leads to a lack of uniformity in the mechanical properties in the section of steel.

[0007] The flange portion, especially, the fillet part (see Fig.1), at which a flange portion and web portion meet, is less strained by rolling and forced to be processed at higher
25 temperature compared with other portions.

[0008] In the section of a shaped steel (e.g., H-shaped

steel), there can be a difference of around 150°C between the three portions of the fillet part, the 1/4 flange and the web (see FIG.1) in the temperature of finishing process. The different mechanical properties depending on portions caused
5 by differences in the rolling temperature history of the portion should be eliminated.

[0009] The degree of finishing temperature dependency in the formation of microstructure during the hot rolling process can be reduced by dispersing the transformation nuclei,
10 such as Ti oxide, in the ferrite grains and thereby expediting transformations in the grains. This leads to uniformity/homogenization of fine-grained microstructure, i.e., uniformity of mechanical properties. Furthermore, since the grain of the microstructure is not only homogenized but also
15 finely grained, this leads to improved toughness.

[0010] The present inventors carried out extensive investigations in order to provide a shaped steel, such as H-shaped steel, which has a low yield ratio and is excellent in toughness and fire resistance and the method for producing
20 the same. During extensive investigations, the inventors recognized the following possible technical issues.

[0011] At first, when the shaped steel excellent in fire-resistance is produced using oxide metallurgy technology, it is required for the processes, especially for casting the
25 slab, billet, bloom, near net-shape slab, ingot, etc., to have complicated steps. Such complicated steps include oxygen

content control before Ti is added and further Ti addition thereafter. Such steps may cause low productivity and high cost in the manufacture of the shaped steels.

[0012] Next, precipitation strengthening technology
5 contributes to the fire-resistance of shaped steels, such as the strength and yield ratio at high temperature. However, in the case where Mo-based carbides, which contain mainly Mo_2C , are employed, such carbides may be solid-soluted in steel at the temperature range of 600 - 650°C if the components are within
10 certain ranges. Consequently contribution to the strength of the steel provided by precipitation strengthening with alloy carbides and alloy carbonitrides may disappear.

[0013] The effect of precipitation strengthening depends on the amount of precipitates of alloy carbonitrides.
15 Alloy carbonitrides include alloy carbides and alloy carbonitrides. Note that one or more metal may be present with the carbides or carbonitrides. Namely, here, alloy carbides mean metal carbides other than cementite. Hereinafter the amount of precipitate is expressed in mol fraction of
20 precipitate and also may be simply referred to as "mol fraction of precipitate". The amount of precipitate depends upon the temperature. Further, such temperature dependence can be influenced by other factors, such as the carbon content of the steel and the thermodynamic characteristics based on the kinds
25 of alloy carbides and alloy carbonitrides and so on.

[0014] As for the carbon content, if the content of C

in the steel is sufficient in comparison with the contents of the metal elements, such as Mo, Ti, V, Nb, Cr, and capable of forming alloy carbonitrides, the amount of precipitate of alloy carbonitrides can be increased as the temperature decreases.

- 5 This is because the content of C capable of forming precipitate increases as the carbon content solid-soluted (present in a solid-solution) in ferrite decreases when the temperature of the steel decreases.

[0015] Accordingly, the strength and yield ratio at the
10 room temperature may be increased excessively even under the same thermal condition, such as the same temperature decrease, if the content of C is high and the mol fraction of precipitate of alloy carbides and alloy carbonitrides is increased excessively.

15

SUMMARY OF THE INVENTION

[0016] From such an analysis of technical issues, the inventors have recognized: i) it is preferred that the alloy carbides and alloy carbonitrides have not only thermodynamic
20 stability, but also have the characteristic of being solid-soluted in the steel at the reheating temperature but not being solid-soluted at temperatures such as 600-650 °C, and ii) alloy carbides and alloy carbonitrides, which are capable of being soluted in the reheating process once and subsequently
25 being precipitated in the cooling process of the hot rolling, can effectively contribute to precipitation strengthening.

[0017] The inventors, after close investigation, recognized that it is preferred to properly control the mol fraction of precipitate of alloy carbides and alloy carbonitrides at a high temperature range and at room
5 temperature range, and that it is preferred to determine the components of the steel considering the following items.

[0018] (i) Suppressing the mol fraction of precipitate of alloy carbides and alloy carbonitrides in a room temperature range to prevent the strength and yield ratio at room
10 temperature from being excessively increased; and (ii) attaining a specific mol fraction of precipitate of alloy carbides and alloy carbonitrides in order to obtain sufficient strength in a high temperature range.

[0019] Taking the above items into consideration, the
15 inventors designed various alloy carbides and alloy carbonitrides and found that the amount of precipitate of alloy carbides and alloy carbonitrides can be controlled by making a proper balance in the amount (content) between the metal elements, such as Mo, Ti, V, Nb, Cr capable of forming alloy
20 carbides and alloy carbonitrides, C and N. It was found that the thermodynamic characteristics can be controlled by making a proper balance in the amount (content) between the metal elements.

[0020] More specifically, in the case where the Mo-based
25 alloy carbide such as Mo_2C is the main constituent of the precipitate, which can be completely solid-soluted in steel at

the temperature range of 600-650°C, contribution to the strength of the steel through precipitation strengthening by alloy carbides and alloy carbonitrides may disappear. However, it is found that the use of MCN type alloy carbonitrides, which are more stable than M₂C type alloy carbides in high temperature ranges, as a partial substitution for the Mo-based alloy carbides (i.e., an increase of precipitate amount of MCN type alloy carbonitrides in comparison with M₂C type alloy carbides, here "M" stands for metal other than ferrum) is very effective to solve the above issue.

[0021] That is, V replacing Mo partially therewith is added in order to form alloy carbonitrides other than Mo-based alloy carbides, and the generation of favorable alloy carbonitrides based mainly on V, Nb and Mo can be controlled by making a proper balance of the added amounts of V, Nb and Mo.

[0022] When referring to an expression such as "a room temperature", this is generally meant to refer to a temperature ranging from about 0°C to about 30°C. However, it is noted that the data at 300°C can be representative of the data at room temperature. This is because the amount of precipitate of alloy carbides and alloy carbonitrides increases very little between room temperature and 300°C. Rather, these precipitates of alloy carbides and alloy carbonitrides, measured in the present invention, occur mainly between 300°C and 600°C. This is due to the fact that as the temperature becomes closer to room

temperature, the diffusion of solid solution elements such as metal elements, carbon and nitrogen, in the steel is extremely lowered in terms of precipitation behavior. More specifically, the equilibrium state of the precipitation remains almost
5 unchanged between room temperature and 300°C. Thus, in the description of the present invention, the precipitation state at a temperature of 300°C can also be representative of that at room temperature. Further, the inventors have selected the temperature of 600°C as being a suitable "high temperature" for
10 the measurement or evaluation of certain mechanical properties, as well as amounts of precipitate of alloy carbides and alloy carbonitrides. However, the "high temperature" is not limited to 600°C and can include other suitable temperatures.

[0023] An object of the invention is to provide a novel
15 shaped steel, such as H-shaped steel, which is used as building construction material, with a low yield ratio and excellence in toughness and fire resistance, and the method for producing the same. The object may be accomplished by the following shaped steel and producing method thereof.

20 [0024] Item 1. A shaped steel, comprising in mass percent (%):

C: 0.03-0.15;

Mo: 0.1- 0.6;

V ≤ 0.35; and

25 N: 0.002-0.012,

and the balance being iron and residual impurities, wherein

(x) a mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C is 0.3 % or more, and

(y) a ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300°C to the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C is 2.0 or less.

[0025] Item 2. The shaped steel according to item 1, further comprising in mass percent (%):

Si: 0.05-0.50;

10 Mn: 0.4-2.0; and

Al \leq 0.01,

wherein the content of V ranges from 0.04 to 0.35%; a flange portion has 50% or more of a ratio of strength, 80 % or less of yield ratio, and 100 J or more of impact strength of Charpy impact test at 0 °C, wherein the ratio of strength = (proof stress of 0.2% at 600°C)/(yield strength at room temperature).

[0026] Item 3. The shaped steel according to items 1 or 2, further comprising one or more of following elements in mass percent (%):

20 Ti: 0.005-0.020;

Nb \leq 0.06 %;

Cr \leq 0.7;

Ni \leq 1.0; and

Cu \leq 1.0,

25 wherein the content of V ranges from more than 0.20 to 0.35 in mass%.

[0027] Item 4. A method for producing a shaped steel according to item 1 by hot rolling after reheating a casted steel, comprising steps of:

(a) reheating the casted steel to 1100 - 1300 °C (as
5 measured at the surface of the casted steel);

(b) hot rolling the casted steel to form the shaped steel;
and

(c) after terminating the hot rolling, naturally cooling
or rapidly cooling then naturally cooling the shaped steel.

10 [0028] Item 5. The method according to item 4, wherein
the step of hot rolling includes water-cooling the shaped steel
at least once to 700°C or less (as measured at the surface of
a flange portion) and then rolling in the heat returning
process.

15 [0029] Item 6. The method according to item 5, wherein
the step of rapid cooling is performed at average cooling rate
of 0.5 to 5.0 °C/s.

[0030] According to the present invention, a shaped
steel, such as H-shaped steel having excellent strength at high
20 temperature and excellent mechanical properties at room
temperature can be obtained by forming alloy carbides and alloy
carbonitrides containing mainly V and Mo in proper amounts by
the specific process such as hot rolling a casted steel
containing specific components. According to the present
25 invention "casted steel" includes a slab, bloom, billet,
near-net shape slab, ingot, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG.1 shows locations where test pieces (specimen) are taken from an H-shaped steel 1. A first location is the center area of the flange 2 in the thickness direction ($1/2 t_2$) and one-fourth ($1/4 B$) position of the total flange width (B) away from the end of flange 2 in the flange width direction. A second location is the center area of the flange 2 in the thickness direction ($1/2 t_2$) and a half ($1/2 B$) position of the total flange width (B) in the flange width direction (fillet part 4). A third location is the center area of the web 3 in the thickness direction ($1/2 t_1$) and a half ($1/2 H$) position of the total web height (H) in the flange width direction.

[0032] FIG.2(a) is a graph showing a relationship between a total mol fraction of precipitate (which is a summation of M_2C type alloy carbides mol fraction and MCN type alloy carbonitrides mol fraction) and temperature, with respect to one example of the invention which contains V of 0.35 %, where the M_2C type alloy carbides partially include V and Nb as a solid solution and the MCN type alloy carbonitrides include V and Nb as main components, and partially include Mo as a solid solution. The vertical axes of Figures 2(a), 2(b) and 3 are mol fraction of precipitates of alloy carbides, alloy carbonitrides and the total of alloy carbides and alloy carbonitrides.

[0033] FIG.2(b) is a graph showing the relationship between total mol fraction of precipitate and temperature,

similar to FIG.2(a), where the V content is 0.22%.

[0034] FIG.3 is a graph showing relationships between temperature and each of the mol fractions of precipitates of M₂C type alloy carbides, MCN type alloy carbonitrides and a total of the M₂C type alloy carbides and the MCN type alloy carbonitrides using conventional technology. It is noted that a conventional method is any method which considers neither the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C, nor the ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300°C to the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C as being 2.0 or less.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] The present invention is described more specifically below. Elements to be contained in the shaped steel of the present invention are described below. In this description, percent "%" represents "% by mass".

[0036] C is an element capable of improving the strength of steel. From the viewpoint of sufficient strength for structural steel, the content of C is preferably 0.03 % or more. C also has an influence on the toughness of the steel of the base material, the weld crack resistance and the toughness at heat affected zones (HAZ). From the viewpoint of such properties, the content of C is preferably 0.15 % or less. Thus, the content of C is preferably 0.03 to 0.15 %.

[0037] Si works as a deoxidizer (or oxygen scavenger) in the process of steel making and also influences the strength of the steel. From the viewpoint of sufficient strength for structural steel, the content of Si is preferably 0.05 % or more.

5 Si also influences the toughness at HAZ since excess amounts of Si may generate M-A (Martensite-Austenite) constituent of hardening structure, which may deteriorate the toughness at HAZ. In view of this, the content of Si is preferably 0.5 % or less. Thus, the content of Si is preferably 0.05 to 0.50 %.

10 [0038] Mn is an element capable of improving the strength and toughness of the mother phase. From this viewpoint, the content of Mn is preferably 0.4 % or more. Mn also has an influence on the crack resistance and the toughness at HAZ. From the viewpoint of such properties, the content of Mn is
15 preferably 2.0 % or less. Thus, the content of Mn is preferably 0.4 to 2.0 %.

[0039] Mo is an element, which is capable of forming Mo-based alloy carbide. In the present invention, it is thought that a shaped steel has excellent strength at room temperature
20 and high temperature since the alloy carbide of Mo is precipitated. For sufficient strength of the shaped steel at high temperatures, the content of Mo is preferably 0.1 % or more. Mo also improves the hardenability of steel. Excess content of Mo may deteriorate the toughness of steel and of HAZ since
25 hardenability may be increased excessively. From the viewpoint of such properties, the content of Mo is preferably

0.6 % or less. Thus, the content of Mo is preferably 0.1 to 0.6 %, more preferably 0.2 to 0.4 %, most preferably 0.2 to 0.3 %.

[0040] V is an element, which is capable of forming alloy carbonitride, and contributes to precipitation
5 strengthening of steel. In the present invention, when V is used with Mo, V can be solid-soluted in the alloy carbide of M_2C , which contains Mo mainly, to form $((Mo,V)_2C)$. Further, V allows Mo to be solid-soluted in the alloy carbonitride of $M(C, N)$, which contains V mainly, to form $((Mo,V)(C,N))$.

10 [0041] Properties of precipitate based on thermodynamics can be adjusted properly by transforming alloy carbides into either or both alloy carbides having the structure of M_2C and/or alloy carbonitrides having the structure of $M(C, N)$ by adjusting the content of V and Mo. For conducting such transformation
15 effectively, it is preferred that the content of V is 0.04 % or more.

[0042] When excess amounts of V are added, the amount of alloy carbonitrides may be increased excessively and the toughness of steel and of HAZ may be deteriorated. Therefore
20 the content of V is preferably 0.35 % or less.

[0043] On the other hand, in order to secure sufficient strength of fire resistance of a shaped steel at 600°C, for example, it is preferable to have a sufficient amount of the alloy carbonitride precipitated in the steel. For this purpose,
25 the content of V is preferably more than 0.20 %. Thus, the content of V is preferably more than 0.20 to 0.35 %.

[0044] The precipitation of V-based alloy carbides having a structure of M_2C has been mainly controlled in order to obtain fire-resistance. However, it is more preferred that forming alloy carbonitrides having a structure of $M(C, N)$ is
5 mainly controlled in order to effectively improve the fire-resistance. From this viewpoint, the content of V is preferably more than 0.20 %.

[0045] N is an element, which is capable of forming alloy carbonitrides. For obtaining sufficient precipitate, the
10 content of N is preferably 0.002 % or more. Further, the content of N is preferably 0.012 % or less since excess amounts of N may cause deterioration of the toughness of steel. Thus, the content of N is preferably 0.002 to 0.012 %.

[0046] Al works as a strong deoxidizer (oxygen
15 scavenger) in the process of steel making. However, Al may form AlN combining with N, which leads to reduction in the amount of alloy carbonitrides (precipitate). Therefore, the Al content is preferably 0.01 % or less.

[0047] Further, in the present invention, other optional
20 components can be added.

[0048] Nb is an element, similar to V and Ti, which is capable of forming alloy carbonitrides, such as $M(C, N)$, and contributing to precipitation strengthening. However, when the content of Nb is more than 0.06 %, it may not further improve
25 the strength of the steel of the present invention by precipitation strengthening since the amount of alloy

carbonitride which is not soluted at 1100-1300 °C, the temperature of heating, prior to hot rolling increases.

[0049] From the viewpoint of improvement of strength by the precipitation of alloy carbonitrides, the Nb content is preferably 0.02 % or more. Thus, the content of Nb is preferably 0.02 to 0.06 %.

[0050] Ti is an element similar to Nb and V, which is capable of forming alloy carbonitrides such as M(C,N) and contributing to precipitation strengthening. In the present invention, Ti is solid-soluted in alloy carbonitride such as M(C,N), which is formed by adding V or a combination of V and Nb, to form alloy carbonitrides such as (V,Ti)(C,N) or (V,Ti,Nb)(C,N). Accordingly, Ti influences the stability of alloy carbonitrides at high temperatures.

[0051] More specifically, alloy carbonitrides such as M(C,N) can extend the thermal stability range to higher temperatures when Ti is present. However, when the content of Ti exceeds 0.02 %, it may not contribute to precipitation strengthening since an amount of alloy carbonitride, which does not become solid-soluted at the heating temperature applied prior to hot rolling, such as 1100 - 1300°C, increases. Therefore, the content of Ti is preferably 0.02 % or less.

[0052] Cr is an element capable of not only improving the strength at room temperature and high temperature by increasing hardenability of steel and precipitation hardening, but is also capable of preventing the grain boundary from being

oxidized (intergranular oxidation) at the surface of the steel and thus, improves the properties of surface of the steel, such as smoothness and evenness. However, when excess amounts of Cr are present, the toughness of the mother phase and the
5 toughness at HAZ may be deteriorated. From this viewpoint, the content of Cr is preferably 0.7 % or less.

[0053] Ni is an element capable of improving the toughness of the mother steel. However, from the viewpoint of cost, the content of Ni is preferably 1.0 % or less.

10 [0054] Cu is an element capable of improving the strength of steel. However, when excess amounts of Cu are present, the hardenability of the steel may be excessively increased and thus the toughness of steel and the toughness at HAZ may be deteriorated. From this viewpoint, the content of
15 Cu is preferably 1.0 % or less.

[0055] The structure of the alloy carbides and alloy carbonitrides and the mol fraction of precipitate of alloy carbides and alloy carbonitrides can be measured by observation and analysis using an electron microscope. As a simpler method,
20 a software program for computing thermodynamic equilibrium can be used.

[0056] With respect to software usable in the present invention, for example, "Thermo-Calc" (manufactured by "Thermo Calc Software, USA)) can be employed for computing
25 thermodynamic equilibrium. As a database, for example, "SSOL" can be also employed to carry out analysis. However, there is

no limitation imposed on the software and database usable in the present invention, as long as the software and the database are dependable.

[0057] In the present invention, when the mol fraction of precipitate of alloy carbonitrides is computed, the total of two types of alloy carbides and alloy carbonitrides, i.e., the mol fraction of precipitate of alloy carbonitrides having a structure of Face Centered Cubic, which is on behalf of MCN type alloy carbonitrides and the mol fraction of precipitate of alloy carbides having a structure of Hexagonal Closed-Packed, which is on behalf of M_2C type alloy carbides, here, is defined as the mol fraction of precipitate of alloy carbides and alloy carbonitrides. Thus, the inventors compute both precipitate amounts of alloy carbides and alloy carbonitrides, and sum them up, and they apply the total precipitate amounts of the alloy carbides and the alloy carbonitrides as the mol fraction of precipitate. On this condition of calculation, the specific mol fraction of precipitate of alloy carbides and alloy carbonitrides are evaluated with respect to various kinds of elements and various temperatures.

[0058] It is preferred that V can be added, replacing partially Mo therewith, since Mo tends to form Mo-based alloy carbides which may be completely solid-soluted in steel at the temperature range of 600-650°C to fail to contribute to precipitation strengthening at such a high temperature. In the range of 0.35% or less of V content of the invention, the

mechanical future at several temperatures, such as room temperature and high temperatures, are evaluated with respect to various kinds of alloy carbides and alloy carbonitrides and various mol fractions of precipitates thereof at various
5 temperatures. This is done to investigate a suitable balance between the content of C and the content of N with particular focus on Mo and V included in alloy carbides and alloy carbonitrides.

[0059] It is preferred that the mol fractions of
10 precipitates of alloy carbides and alloy carbonitrides are estimated by computing the thermodynamic equilibrium assuming that alloy carbides, which contain Mo mainly and in which V and/or Nb can also be solid-soluted, is "M₂C type alloy carbide", and alloy carbonitrides, which contain V and Nb mainly and in
15 which Mo can be solid-soluted, is "MCN type alloy carbonitride". As the mol fractions of precipitates in the actual process using continuous cooling are slightly different from the mol fractions calculated above, it is preferable to make some corrections.

20 [0060] Mechanical properties at 600°C, especially proof stress of 0.2%, are preferred to attain excellent fire-resistance. Proof stress of 0.2% is preferably 157 MPa or more.

[0061] Changing the balance of elements, C and N used
25 in the present invention, the properties of the shaped steel are evaluated at a range of 0-1.0 % of the mol fraction of

precipitate of alloy carbides and alloy carbonitrides. It is found that the mol fraction of precipitate of alloy carbides and alloy carbonitrides is preferably 0.3 % or more.

[0062] Further, in order to resolve a problem that the strength and yield ratio at room temperature is excessively increased, a suitable ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides, i.e., the ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300 °C and that at 600 °C, and suitable mechanical properties at several high and room temperatures, are investigated. In order to simultaneously attain both a suppression of excessive increase of the strength at room temperature and an excellent fire-resistance, it is found preferable to meet the following conditions: i) tensile strength of the flange portion is 400 MPa or more; ii) impact strength of Charpy impact test is 100 J or more at 0 °C; and iii) 0.2% proof stress at 600 °C is 157 MPa or more. Conditions i) and ii) are mainly for the properties at room temperature and condition iii) is mainly for the fire-resistance.

[0063] By changing the balance of elements, C and N used in the present invention in the presence of V replacing Mo partially therewith, the properties of the shaped steel are evaluated at range of 0-5.0 % of the mol fraction of precipitate of alloy carbides and alloy carbonitrides. It is found that the ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300 °C and at 600 °C is preferably

2.0 or less.

[0064] From the above investigation, precipitates of alloy carbides and alloy carbonitrides, which have excellent properties, can be newly obtained, as shown in Fig. 2 (a) and
5 (b). In Fig.2(a) and (b), the amount of precipitate of alloy carbides of M_2C type containing partly V and Nb as a solid solution, alloy carbonitrides of MCN type containing mainly V, Nb and partly Mo as a solid solution, and the total of M_2C type alloy carbides and MCN type alloy carbonitrides are shown.

10 [0065] Fig.2 (a) shows the case where the content of V is 0.35%. The mol fraction of precipitate of alloy carbides and alloy carbonitrides at the temperature of 600 °C is 0.52%, which is within the range of the invention (0.3 or more). When the temperature is shifted from 600 °C to 300 °C, the mol fraction
15 of precipitate of alloy carbides and alloy carbonitrides increases from about 0.52 % to about 0.54 %. The ratio of these is approximately 1.03, satisfying the condition of 2.0% or less of the invention.

[0066] Fig.2 (b) shows the case where the content of V
20 is 0.22%. The mol fraction of precipitate of alloy carbides and alloy carbonitrides at the temperature of 600 °C is 0.52%, which is within the range of the invention (0.3 % or more). When the temperature is shifted from 600 °C to 300 °C, the mol fraction of precipitate of alloy carbides and alloy carbonitrides
25 increases from about 0.52 % to about 0.59 %. The ratio between these is approximately 1.14, satisfying the condition of 2.0%

or less of the invention.

[0067] Thus, it is found that the composition design described above can simultaneously attain both a suppression of excessive increase of strength at room temperature and an
5 excellent fire-resistance at 600°C.

[0068] Fig.3, on the other hand, shows the results where a conventional method is applied to a steel whose composition is within the range of the invention. As shown in Fig. 3, the mol fraction of precipitate of alloy carbides and alloy
10 carbonitrides at 600 °C is within that of the invention (0.30% or more). However, when the temperature is shifted from 600 °C to 300 °C, the mol fraction of precipitate of alloy carbides and alloy carbonitrides increases drastically from about 0.61 % to about 1.42 %. The ratio of the mol fraction of precipitate
15 at 300°C and 600°C is 2.3, which is outside the range of the invention (2.0 or less). Fig.3 shows that the conventional method has a problem in that the strength at 300 °C is excessively high. It is noted that a conventional method is any method which considers neither the mol fraction of precipitate of alloy
20 carbides and alloy carbonitrides at 600°C, nor the ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300°C to the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C as being 2.0 or less.

25 [0069] The size of precipitates such as alloy carbides and alloy carbonitrides has an influence on the strength. In

accordance with the desirable strength, it is preferred to make the precipitate fine-grained, for instance, to the size of 10-1000nm. It is preferred that solution treatment be conducted prior to hot rolling and precipitate be formed during cooling after hot rolling, or precipitate be formed by keeping the temperature of the steel at about 600 °C.

[0070] In the present invention, there is no specific limitation with respect to the ratio of the precipitate amounts between MCN type alloy carbonitrides having a stable less-temperature (only temperature range of 300°C to 600°C) -dependent precipitate amount and M₂C type alloy carbides having a temperature-dependent precipitate amount. It can be said, however, that the ratio, i.e., precipitate of MCN type alloy carbonitrides / precipitate of M₂C type alloy carbides (hereinafter referred to as the ratio of MCN/M₂C), is larger than that achieved by conventional methods. For example, a ratio of MCN/M₂C of 0.7 or more provides a significant effect at high temperatures, for example, 600°C. When the total amount of M₂C is reduced, however, the ratio of MCN/M₂C may not be a determining factor. In other words, the ratio of MCN/M₂C of 0.7 or more is not a required condition of the invention.

[0071] The reason for the limitation in the hot rolling process is as follows. First the casted steel, such as the slab, billet, bloom, near-net shape slab, ingot, etc., is reheated to a range between 1100 and 1300°C. The reason for the limitation of the temperature is to ensure a sufficient temperature to

allow the casted steel to be processed in an austenite range and to sufficiently develop precipitation strengthening by making alloy carbides and alloy carbonitrides once a solid-solution in the process of hot rolling of the shaped
5 steel.

[0072] After reheating, the casted steel is subjected to a hot rolling process. The hot rolling process basically includes a break-down process performed by groove rolling, intermediate rolling, and finishing rolling. The intermediate
10 rolling process may be performed by any of a group of intermediate universal rolling machines including an edger rolling machine and a universal rolling machine, and the finishing rolling process may be performed by a universal rolling machine. The above-mentioned process also includes a
15 rolling process using a skew roll for controlling the height of the web portion of the shaped steel.

[0073] In the break down process of the above rolling process, the casted steel is rolled in the width direction by a plurality of rolls, each roll has a groove of which bottom
20 width is different to each other and the bottom part has a projected portion in the middle of the groove bottom. This is to ensure an appropriate flange width and web height.

[0074] In the intermediate rolling process, an appropriate flange width is obtained by an edger rolling machine
25 and appropriate web thickness and flange thickness are obtained by an universal rolling machine. Furthermore in the finishing

rolling process, shaped steel with predetermined size is formed while keeping the surface temperature of the flange portion, for instance, at 800°C or more.

[0075] The present invention can be preferably applied
5 to a shaped steel of which the web thickness ranges from 9 mm to 40 mm, the flange thickness ranges from 12 mm to 60 mm, the web height is about 500 mm and the flange width ranges from 200 mm to 500 mm.

[0076] In the hot rolling process after the reheating,
10 it is preferable that the shaped steel is water-cooled at least once to 700°C or less as measured at the surface of the flange portion and then rolled in the heat returning process.

[0077] As described above, the temperatures of the fillet and the flange portion are usually higher than that of
15 the web portion due to the shape of shaped steel. In order to reduce the non-uniformity of the temperatures, the water-cooling of the flange portion and the rolling in the heat returning process are carried out at least once. Preferably this cyclic process of water-cooling and rolling can be repeatedly
20 performed according to the size of shaped steel and the number of rolling passes.

[0078] In this invention, after finishing the hot rolling process, it is preferable that the shaped steel is either naturally cooled, or rapidly cooled, for instance, at
25 least once, and then naturally cooled. In this cooling process the microstructure of the steel is fine-grained, which leads

to improvements of strength at room temperatures, toughness and strength at high temperatures.

[0079] In the case where the rapid cooling is performed before natural cooling, the average cooling rate should preferably be between 0.5 and 5.0°C/s so that the microstructure can be further fine-grained.

[0080] In the present invention, after performing the cooling process above-described, shaped steel excellent in fire-resistance having the following mechanical properties can be manufactured. That is, for example: mechanical properties where strength ratio defined by (0.2% proof stress at 600°C)/(yield strength at room temperature) is 50% or more, yield ratio at room temperature is 80% or less and Charpy impact absorption energy at 0°C is 100J or more; where the flange portion tensile strength at room temperature is 400 MPa class (grade), 0.2% proof stress at 600°C is 157 MPa or more and Charpy impact absorption energy at 0°C is 100J or more; and where the flange portion tensile strength at room temperature is 490 MPa class, 0.2% proof stress at 600°C is 217 MPa or more and Charpy impact absorption energy at 0°C is 100J or more.

EXAMPLES

[0081] Examples of the present invention are described below. However conditions described in the examples are considered as illustrative only and the present invention is not restricted to these conditions. The invention can be applied

in other various conditions without departing from the gist of the invention for accomplishing the object of the invention.

[0082] The steel blooms and billets used in these examples, having component(s)/composition(s) shown in Table 1 and the mol fractions of precipitates are predetermined through equilibrium calculation by the "Thermo-Calc" at 600 °C and 300°C, are melted in a steel converter and blooms and billets of about 240-300mm in thickness are cast in a continuous casting process. In Table 1, "tr" means "impossible to detect" or "unavoidable impurities".

[0083] The conditions of examples "a - g" of comparison steels, are outside the range of the invention. The conditions of components of example "a - c" are within that of the invention, but the mol fractions of precipitates of alloy carbides and alloy carbonitrides at 600 °C are not within the range of the invention (0.3 % and more). As for examples "d - g", each of the ratios of the mol fraction of the precipitate of alloy carbides and alloy carbonitrides at 300 °C to the mol fraction of the precipitate of alloy carbides and alloy carbonitrides at 600 °C, i.e., (the mol fraction at 300°C)/(the mol fraction at 600°C) are outside the range of the invention (2.0 and less).

[0084] In TABLE 1, the ratio of mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300 °C to that at 600 °C shown in the rightmost column is not completely identical to the value calculated by each of the mol fraction of precipitate of alloy carbides and alloy

carbonitrides at 300 °C and that at 600 °C. The difference is caused by number of significant digits, because each of the mol fraction of precipitate of alloy carbides and alloy carbonitrides are calculated to three decimal places, which is
5 rounded off.

[0085] Each of the casted steel are reheated to 1100 - 1300°C and then subjected to the hot rolling process including a break-down process performed by a groove rolling process, an intermediate rolling process of a group of intermediate
10 universal rolling machine including an edger rolling machine and a universal rolling machine, and a finishing rolling process performed by a universal rolling machine to form a H-shaped steel of predetermined size.

[0086] In the above hot rolling process, the web height
15 of H-shaped steel is controlled by a rolling process using a skew roll.

[0087] H-shaped steel, of which the web thickness ranges from 9 mm to 40 mm, the flange thickness ranges from 12 mm to 60 mm, the web height is about 500 mm and the flange width ranges
20 from 200 mm to 500 mm, are manufactured.

[0088] FIG. 1 shows a C-section of H-shaped steel, which is created by cutting the steel in a lateral direction (not longitudinal direction). The mechanical properties of the manufactured H-shaped steel are obtained by carrying out a
25 variety of tests using a test piece (specimen). FIG.1 shows locations from where the test pieces (specimen) are taken. A

first location is the center area of flange 2 in the thickness direction ($1/2 t_2$) and one-fourth ($1/4 B$) position of the total flange width (B) away from the end of flange 2 in the flange width direction. A second location is the center area of flange
5 2 in the thickness direction ($1/2 t_2$) and a half ($1/2 B$) position of the total flange width (B) in the flange width direction (fillet part). A third location is the center area of web 3 in the thickness direction ($1/2 t_1$) and a half ($1/2 H$) position of the total web height (H) in the flange width
10 direction. The mechanical properties at the above ($1/4 B$) position can represent the mechanical properties of the flange portion of H-shaped steel. However, the mechanical properties at the above three locations are measured and an average value of the mechanical properties of the three locations and a value
15 of the mechanical property of the web portion (third location) are checked to confirm that excessive strengthening of mechanical properties with the web portion can be prevented. That is, a ratio of the value of the web portion to the average value of the three locations is calculated.

20 [0089] TABLE 2 illustrates the results of the above test, i.e., yield strength at room temperature, tensile strength at room temperature, yield ratio at room temperature, Charpy impact absorption energy at 0°C (3 points average value according to JIS, the specimen is JIS NO.4 (full size), with
25 2mm V-shape notch), 0.2% proof stress at 600°C according to JIS A2, and ratio of 0.2% proof stress at 600°C and yield strength

at room temperature, for instance, according to JIS NO. 13A or 13B, depending upon the thickness of the shaped steel. As for the Charpy impact test, the data in TABLE 2 represents measured values of the fillet part (1/2 B) which has a lower value in the Charpy impact test than that of any other part in the section of the H-shaped steel. As for the 0.2% proof stress at 600°C, the data in TABLE 2 represent measured values of the (1/4 B) position in the flange portion. The value of the (1/4 B) position represents the strength of the H-shaped steel. There are two different classes (grades) of strength required to the steel. One is SN400 class, where the tensile strength at room temperature is 400 MPa and more, the other is SN490 class, where the tensile strength at room temperature is 490 MPa and more. As for SN400 class, examples whose strengths are approximately 400-520 MPa are shown. As for SN490 class, examples whose strengths are approximately 500-611 MPa are shown. In TABLE 2, the results are described according to the classes. Also, the ratio of the value of the mechanical property of the web portion to that of the average value of the three locations is calculated and listed therewith.

[0090] The steel of the invention satisfy such conditions as the components, and the mol fraction of precipitate of the alloy carbides and alloy carbonitrides. The mechanical properties of the steel of the invention attain the target properties both at high temperature (600 °C) and room temperature, such as yield strength, tensile strength, Charpy

impact absorption energy at 0°C, particularly the strength ratio of the flange part of the steel is defined as (0.2 % proof strength at 600 °C)/(yield strength at room temperature) and yield ratio at room temperature.

5 [0091] The comparative examples, despite of having the same components as the steel of the present invention, do not satisfy at least one of the mechanical properties at room temperature and high temperature because they do not meet the requirements of mol fraction of precipitate of alloy carbides
10 and alloy carbonitrides in the present invention.

[0092] Comparative steels "c, f, g" are insufficient in the Charpy impact absorption energy at 0°C in comparison with the steel of the present invention (100 J or more). Comparative steels "a, b", belonging to class SN400, do not reach the target
15 value of 0.2% proof strength at 600 °C, i.e., 157MPa and more. Comparative steels "d, e", belonging to class SN490, have a 0.2 % proof strength at 600 °C of 206, 212MPa respectively, which do not reach the target value of 217MPa and more. The strength ratios of comparative steels "d, e" do not reach the target value
20 of 50% or more.

[0093] As previously mentioned, the present invention provides for shaped steel excellent in fire-resistance and having the desired strength at high temperature and mechanical properties at room temperature by forming alloy carbides and
25 alloy carbonitrides mainly made of V and Mo under the proper balance of added amounts of V and Mo.

[0094] The shaped steel of the present invention is very useful as a construction material and has great industrial applicability.

[0095] All cited patents, publications, copending applications, and provisional applications referred to in this application are herein incorporated by reference.

[0096] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the present invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

* * * * *

High V content system

TABLE 1

metal carbide and metal carbonitride precipitation by computing thermodynamic equilibrium																
metal carbide and metal carbonitride precipitation by computing thermodynamic equilibrium																
	NO	C	Si	Mn	Mo	V	N	Al	Ti	Nb	Cr	Ni	Cu	mol fraction at 600 °C (%)	mol fraction at 300 °C (room/ordinary temperature) (%)	ratio of mol fractions 300°C/600°C
	1	0.05	0.20	0.70	0.30	0.25	0.0043	0.010	tr	tr	tr	tr	tr	0.53	0.54	1.03
	2	0.05	0.20	0.60	0.15	0.35	0.0045	0.008	tr	tr	tr	tr	tr	0.54	0.55	1.03
	3	0.10	0.20	0.60	0.40	0.30	0.0045	0.008	tr	tr	tr	tr	tr	0.98	1.12	1.15
	4	0.05	0.15	1.00	0.30	0.20	0.0040	0.008	tr	tr	tr	tr	tr	0.52	0.60	1.17
	5	0.07	0.10	1.05	0.30	0.35	0.0041	0.008	tr	tr	tr	tr	tr	0.73	0.75	1.03
	6	0.05	0.15	1.30	0.30	0.20	0.0070	0.008	tr	tr	tr	tr	tr	0.54	0.63	1.18
	7	0.06	0.10	1.00	0.30	0.30	0.0073	0.008	tr	tr	0.2	tr	tr	0.65	0.67	1.03
	8	0.05	0.10	1.05	0.25	0.20	0.0071	0.010	tr	0.03	tr	tr	tr	0.54	0.61	1.14
	9	0.06	0.15	1.20	0.30	0.25	0.0070	0.010	0.012	tr	tr	tr	tr	0.64	0.73	1.14
	10	0.05	0.20	1.20	0.30	0.20	0.0070	0.010	0.008	0.02	tr	0.7	0.7	0.54	0.62	1.16
	11	0.05	0.15	0.70	0.30	0.21	0.0041	0.010	tr	tr	tr	tr	tr	0.52	0.60	1.16
	12	0.10	0.20	0.60	0.40	0.25	0.0045	0.008	tr	tr	tr	tr	tr	0.89	1.16	1.31
	13	0.06	0.15	0.72	0.40	0.10	0.0044	0.009	tr	0.05	tr	tr	tr	0.60	0.76	1.27
	14	0.05	0.15	0.60	0.30	0.30	0.0047	0.008	tr	tr	tr	0.8	0.8	0.54	0.59	1.11
	15	0.12	0.10	1.01	0.40	0.35	0.0042	0.010	tr	tr	tr	tr	tr	1.11	1.35	1.21
	16	0.05	0.15	1.30	0.30	0.20	0.0070	0.008	tr	tr	tr	tr	tr	0.42	0.63	1.50
	17	0.08	0.10	1.00	0.30	0.30	0.0073	0.008	tr	tr	tr	tr	tr	0.68	0.90	1.32
	18	0.05	0.10	1.05	0.20	0.21	0.0071	0.010	tr	0.03	tr	tr	tr	0.54	0.60	1.12
	19	0.06	0.20	1.10	0.30	0.15	0.0070	0.010	0.012	tr	0.6	tr	tr	0.37	0.63	1.73
	20	0.05	0.20	1.00	0.30	0.20	0.0070	0.010	0.008	tr	0.2	tr	tr	0.43	0.64	1.48
	a	0.10	0.15	0.71	0.30	tr	0.0042	0.010	tr	0.02	tr	tr	tr	0.24	0.92	3.79
	b	0.10	0.15	0.72	0.30	tr	0.0042	tr	tr	0.04	tr	tr	tr	0.25	0.95	3.85
	c	0.10	0.15	0.75	0.30	tr	0.0044	0.010	tr	0.06	tr	tr	tr	0.27	1.06	3.87
	d	0.10	0.15	0.99	0.30	0.07	0.0073	0.008	0.010	0.04	0.2	tr	tr	0.41	1.38	3.37
	e	0.10	0.15	1.00	0.30	0.07	0.0074	0.008	0.010	0.06	0.2	tr	tr	0.34	1.36	3.97
	f	0.12	0.15	1.00	0.30	0.07	0.0071	0.001	0.005	0.04	0.2	tr	tr	0.41	1.65	3.97
	g	0.12	0.15	1.00	0.30	0.07	0.0073	0.001	0.010	0.06	0.2	tr	tr	0.45	1.63	3.61

TABLE 2	high V content system							mechanical properties at room temperature					mechanical property at high temperature	
	components	strength class	water-cooling while rolling	rapid cooling (0.5~50°C/s)	thickness of flange/web (mm)	part of H-shaped steel	yield strength YP (MPa)	tensile strength TS (MPa)	yield ratio (%)	ratio of yield strength: web/average	ratio of tensile strength: web/average	Charpy impact absorption energy at 0° C (J) *1		0.2% proof stress at 600° C PS(MPa) *2
H-shaped steel of the invention	1		n/a	n/a	20/35	web portion average	334	426	78.4	104	1.03	389	182	54.5
	2	SN400 class	applied	n/a	14/26	web portion average	322	415	77.6	1.03	1.02	346	185	54.7
							338	427	79.2					
	3	SN400 class	applied	n/a	13/21	web portion average	349	441	79.1	1.04	1.02	264	191	54.7
							335	432	77.5					
	4	SN400 class	applied	applied	13/21	web portion average	384	502	78.5	1.04	1.01	217	221	56.1
							379	498	76.1					
	5	SN400 class	applied	n/a	14/26	web portion average	417	542	76.9	1.03	1.02	280	229	54.9
							406	533	76.2					
	6	SN400 class	applied	n/a	14/26	web portion average	432	579	74.6	1.04	1.02	455	231	53.5
416							567	73.4						
7	SN490 class	applied	applied	18/28	web portion average	389	513	75.8	1.04	1.02	189	235	60.4	
						375	505	74.3						
8	SN490 class	applied	n/a	20/35	web portion average	424	554	76.5	1.04	1.02	251	233	55.0	
						406	545	74.5						
9	SN490 class	applied	n/a	20/35	web portion average	417	548	76.1	1.02	1.01	261	222	53.2	
						408	542	75.3						
10	SN490 class	applied	n/a	11/18	web portion average	438	568	76.8	1.03	1.01	191	228	52.3	
						422	585	74.7						

TABLE 2 (continued 1) high V content system

components	strength class	water-cooling while rolling	rapid cooling (0.5~50°C /s)	thickness of flange/web b (mm)	part of H-shaped steel	mechanical properties at room temperature						mechanical property at high temperature		
						yield strength YP (MPa)	tensile strength TS (MPa)	yield ratio (%)	ratio of yield strength: web/average	ratio of tensile strength: web/average	Charpy impact absorption energy at 0° C (J) *1	0.2% proof stress at 600° C PS(MPa) *2	strength ratio: (0.2% proof strength at 600° C)/(yield strength at room temperature) (%)*3	
H-shaped steel of the invention	11	n/a	n/a	20/35	web portion	329	431	76.3	1.04	1.02	297	179	54.4	
						average	317	421						75.3
	12	SN400 class	applied	n/a	13/24	web portion	341	430	79.3	1.03	1.05	331	182	53.4
							average	331	410					
	13	SN400 class	applied	n/a	13/21	web portion	331	425	77.9	1.04	1.04	221	184	55.6
							average	317	408					
	14	SN400 class	applied	applied	13/21	web portion	384	512	75.0	1.05	1.04	184	220	57.3
							average	367	494					
	15	SN400 class	applied	n/a	13/24	web portion	398	544	73.2	1.05	1.03	201	234	58.8
							average	378	527					
	16	SN400 class	applied	n/a	13/24	web portion	441	567	77.8	1.05	1.03	287	246	55.8
							average	420	552					
	17	SN490 class	applied	applied	18/28	web portion	425	534	79.6	1.04	1.03	174	241	56.7
							average	407	517					
	18	SN490 class	applied	n/a	20/35	web portion	430	566	76.0	1.05	1.04	189	246	57.2
							average	411	543					
	19	SN490 class	applied	n/a	18/34	web portion	411	546	75.3	1.04	1.04	284	227	55.2
							average	397	526					
	20	SN490 class	applied	n/a	11/18	web portion	440	571	77.1	1.04	1.03	241	237	55.2
							average	425	555					

TABLE 2 (continued 2) high V content system

components	strength class	water-cooling while rolling	rapid cooling (0.5~50°C /s)	thickness of flange/web (mm)	part of H-shaped steel	yield strength YP (MPa)	tensile strength TS (MPa)	yield ratio (%)	ratio of yield strength: web/average	ratio of tensile strength: web/average	Charpy impact absorp-tion energy at 0° C (J) *1	0.2% proof stress at 600° C PS(MPa) *2	strength ratio: (0.2 % proof strength at 600 ° C)/(yield strength at room temperature) (%) *3	mechanical property at high temperature						
														mechanical property at room temperature	mechanical property at high temperature					
H-shaped steel of comparison	a	applied	n/a	20/35	web portion average	299	421	71.0	1.15	1.13	386	124	41.5							
						260	374	69.5												
	b	applied	n/a	13/21	web portion average	365	486	75.1	1.13	1.11	179	152	41.6							
						323	436	74.1												
	c	applied	n/a	13/21	web portion average	382	519	73.6	1.12	1.09	97	155	40.6							
						342	476	71.8												
	d	applied	n/a	14/26	web portion average	415	575	72.2	1.1	1.09	197	206	49.6							
						377	529	71.3												
	e	applied	n/a	14/26	web portion average	426	570	74.7	1.12	1.1	154	212	49.8							
						382	520	73.5												
	f	applied	n/a	13/21	web portion average	424	611	69.4	1.09	1.08	86	225	53.1							
						389	584	69.0												
	g	applied	n/a	20/35	web portion average	433	591	73.3	1.09	1.08	49	227	52.4							
						399	547	72.9												
target properties :														SN400 class	235-355	400-510	< 80	100 <	157 <	50 <
target properties :														SN490 class	325-445	490-610	< 80	100 <	217 <	50 <

Bold number : The bold numbers denote target property is unsatisfied.

*1 test piece location for Charpy impact test : flange 1/2 B (fillet part)

*2 test piece location for tensile test at high temperature : flange 1/4 B

*3 yield strength at room temperature at web portion; 0.2 % proof strength at 600 ° C at flange 1/4 B

CLAIMS

1. A shaped steel, comprising in mass percent (%):

5 C: 0.03-0.15;

Mo: 0.1- 0.6;

$V \leq 0.35$; and

N: 0.002-0.012,

and the balance being iron and residual impurities, wherein

10 (x) a mol fraction of precipitate of alloy carbides and alloy carbonitrides at 600°C is 0.3 % or more, and

(y) a ratio of the mol fraction of precipitate of alloy carbides and alloy carbonitrides at 300°C to the mol fraction of precipitate of alloy carbides and alloy carbonitrides at
15 600°C is 2.0 or less.

2. The shaped steel according to claim 1, further comprising:

Si : 0.05-0.50;

20 Mn : 0.4-2.0; and

Al \leq 0.01,

wherein the amount of V ranges from 0.04 to 0.35 in mass %, a flange portion of the shaped steel has 50% or more of a ratio of strength, 80 % or less of yield ratio, and 100 J or more of
25 impact strength of Charpy impact test at 0°C, wherein the ratio

of strength = (proof stress of 0.2% at 600°C)/(yield strength at room temperature).

3. The shaped steel according to claim 1 or 2, further
5 comprising one or more of following elements in mass percent (%) :

Ti : 0.005-0.020;

Nb \leq 0.06 %;

Cr \leq 0.7;

10 Ni \leq 1.0; and

Cu \leq 1.0.

wherein the content of V ranges from more than 0.20 to 0.35 in mass%.

15 4. A method for producing a shaped steel according to claim 1 by hot rolling after reheating a casted steel, comprising steps of:

(a) reheating the casted steel to 1100 - 1300 °C;

(b) hot rolling the casted steel to form the shaped steel;

20 and

(c) after terminating the hot rolling, naturally cooling or rapidly cooling then naturally cooling the shaped steel.

5. The method according to claim 4, wherein the step of
25 hot rolling includes water-cooling the shaped steel at least once to 700°C or less as measured at the surface of a flange

portion of the shaped steel and then rolling in the heat returning process.

6. The method according to claim 5, wherein the step of
5 rapid cooling is performed at an average cooling rate of 0.5
to 5.0°C/s.

* * * * *

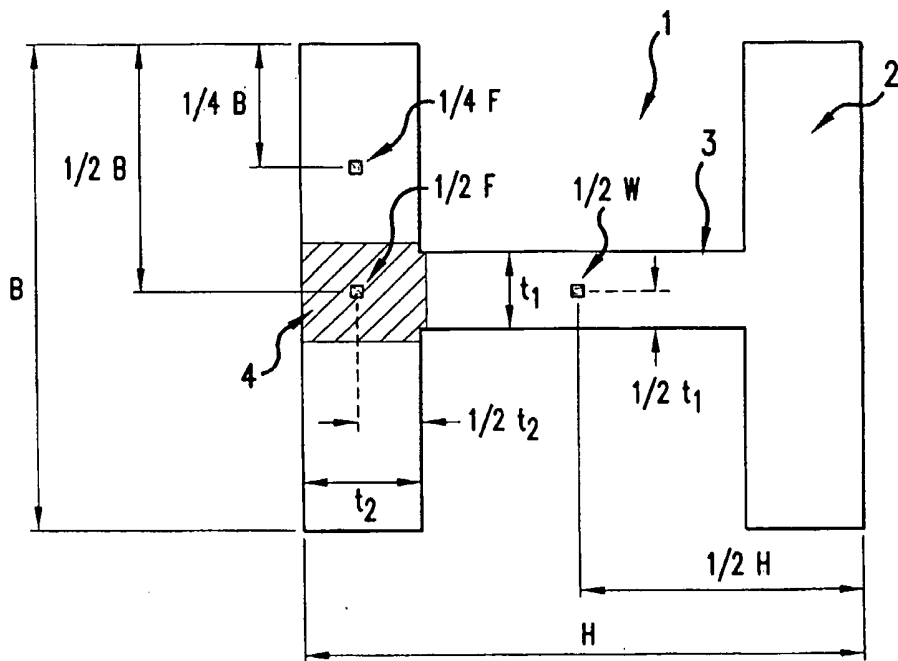


FIG.1

COMPONENTS: 0.05C-0.15Si-0.7Mn-0.3Mo-0.35V-0.006Nb-0.004N
 mol FRACTION OF PRECIPITATION OF (M₂C TYPE CARBIDE + MCN
 TYPE CARBONITRIDE) AT 600°C: 0.53%
 RATIO OF THE mol FRACTION AT 300°C TO THAT OF 600°C: 1.03

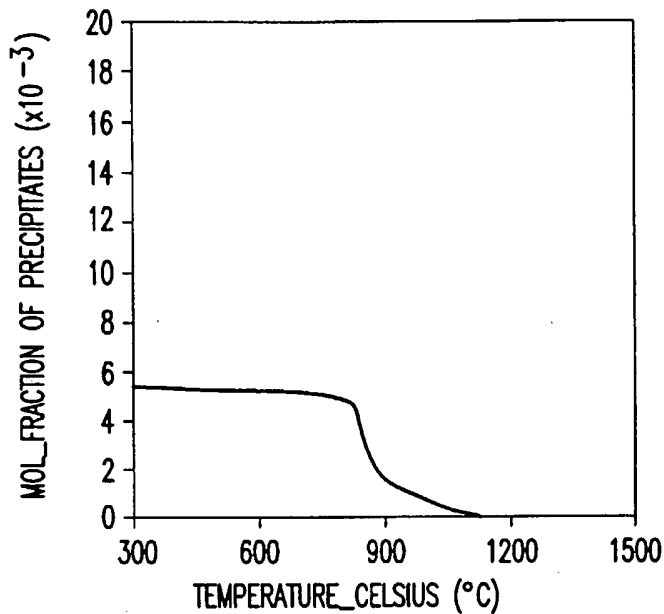


FIG.2(a)

COMPONENTS: 0.05C-0.15Si-0.7Mn-0.3Mo-0.22V-0.002Nb-0.004N
 mol FRACTION OF PRECIPITATION OF (M₂C TYPE CARBIDE + MCN
 TYPE CARBONITRIDE) AT 600°C: 0.52%
 RATIO OF THE mol FRACTION AT 300°C TO THAT OF 600°C: 1.14

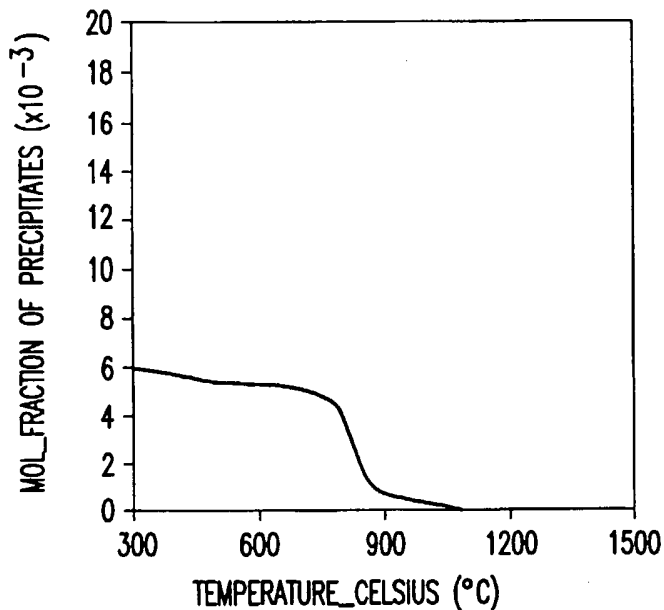


FIG.2(b)

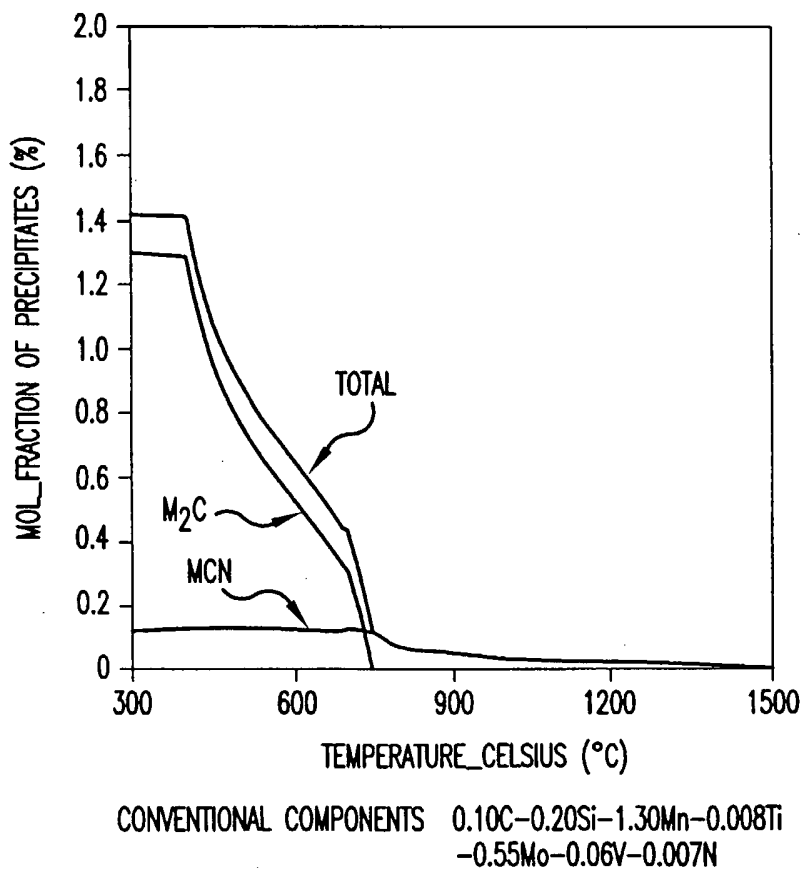


FIG.3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP2005/013999

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 C22C38/00 C22C38/12 C22C38/26		
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) IPC 7 C22C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX		
C. 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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<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents :		
A document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *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 19 September 2005		Date of mailing of the international search report 28/10/2005
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Catana, C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP2005/013999

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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