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(54) **High-strength steel sheets and processes for production of the same**

Hochfeste Stahlbleche und Verfahren zur deren Herstellung

Feuilles d'acier très résistantes et leurs procédés de production

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- **SUGIMOTO K ET AL: "DUCTILITY AND FORMABILITY OF NEWLY DEVELOPED HIGH STRENGTH LOW ALLOY TRIP-AIDED SHEET STEELS WITH ANNEALED MARTENSITE MATRIX", ISIJ INTERNATIONAL, IRON AND STEEL INSTITUTE OF JAPAN, TOKYO, JP, vol. 42, no. 8, 1 January 2002 (2002-01-01), pages 910-915, XP001182009, ISSN: 0915-1559**

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Description

[Technical Field]

[0001] The present invention relates to a high strength steel sheet for which high press formability is required, typically including steel sheets for automobiles, particularly to a high strength steel sheet with both elongation and stretch-flanging performance and a method for manufacturing the same.

[Background Art]

[0002] High strength steel sheets, which are generally used by being press-molded, are used in industrial product such as automobiles, electric devices and industrial machines. Since high strength steel sheets are used for the purpose of lightening industrial products, they need not only have high strength, but also have the ability to form various configurations of the products. Accordingly, it is required for high strength steel sheets to have excellent press formability. To meet this requirement, high-strength steel sheets having excellent elongation and stretch-flanging performance, which are necessary for improving press formability, are required.

[0003] Examples of known steels having such characteristics include dual phase steel (DP steel) whose metal structure is composed of a ferrite phase and a martensite phase, as described in Patent document 1. Since this DP steel can ensure ductility (elongation) due to its soft ferrite and strength due to its rigid martensite, it has both strength and elongation (in particular, uniform elongation). However, because of the coexistence of soft ferrite and rigid martensite, distortion (stress) is concentrated at the interface of the two phases when deformed, and therefore the interface is likely to serve as the starting point of rupture, thereby disadvantageously preventing ensuring stretch-flanging performance (local elongation).

[0004] Examples of steel sheets which expectedly have ductility (especially, uniform elongation) higher than those of DP steels include TRIP steels utilizing the TRIP (Transformation Induced Plasticity) phenomenon, as described in Patent document 2. This TRIP steel is a steel sheet in which uniform elongation is increased by transforming retained austenite into martensite during deformation (working-induced transformation). However, since martensite which has been transformed from retained austenite in the TRIP steel is extremely hard, it likely serves as the starting point of rupture, lowering the stretch-flanging performance of the steel sheet.

[0005] Other methods of improving the stretch-flanging performance of the high strength steel sheets include that in which the metal structure is single-phase structure and localization of process distortion is suppressed by homogenizing the in the metal structure, and that in which a difference in strength between a soft phase having a multi-phase metal structure and a hard phase is reduced.

Since martensite single-phase structure steel sheet has a uniform structure, it is known as a steel sheet which has both strength and stretch-flanging performance. However, the martensite single-phase structure steel sheet disadvantageously has low ductility, and insufficient elongation.

[0006] Patent document 3 discloses a high-stretch-strength cold-rolled steel sheet in which martensite single-phase structure is achieved by justifying the composition and heat treatment conditions of the steel sheet, and tensile strength is 880 to 1170 MPa. That is, the high-stretch-strength cold-rolled steel sheet of Patent document 3 is produced by heating and retaining a steel sheet having a predetermined composition range at 850°C, which is normally reachable temperature industrially, to transform the steel sheet into austenite, and then rendering it a martensite single-phase structure. A steel sheet of a martensite single-phase structure produced by this invention has a tensile strength of 880 to 1170MPa, and thus has excellent stretch-flanging performance. However, it has elongation EL (%) lower than 8% and thus has low ductility. In the high strength steel sheet of the invention of Patent document 3, if ductility is improved, press formability can be further improved.

[0007] Moreover, Patent document 4 discloses a method for manufacturing a high tensile strength steel sheet, in which a steel sheet in which the ratio by volume of a low-temperature transformation phase comprising a martensite phase and others and a retained austenite phase is 90% or higher of the entire metal structure is heated and retained to produce a two phase region: a ferrite phase and an austenite phase, a metal structure comprising a fine ferrite phase which has succeeded the laths of the low-temperature transformation phase and the austenite phase is provided, and finally the steel sheet is given such a metal structure that comprises ferrite and the low-temperature transformation phase finely dispersed in the form of laths.

[0008] However, since the steel sheet produced by the steelmaking method disclosed in Patent document 4 has a relatively high cooling stop temperature in the steelmaking process, a large amount of bainite is deposited, while a large amount of retained austenite also remains therein, and therefore the steel sheet has excellent ductility, but has insufficient stretch-flanging performance. By the steelmaking method of Patent document 4, a steel sheet which is excellent in both elongation and stretch-flanging performance cannot be produced.

[Patent document 1] Japanese Unexamined Patent Application Publication (JP-A) No. S55-122820
[Patent document 2] JP-A-S60-43425
[Patent document 3] Japanese Patent No. 3729108
[Patent document 4] JP-A-2005-272954

JP 2005-336526 discloses a retained austenitic steel sheet comprising, by mass, 0.06 to 0.6% C, Si+Al: 0.5 to 3%, 0.5 to 3% Mn, ≤0.15% (excluding 0%) P and ≤0.02% (excluding 0%) S, and comprising tempered martensite, the space factor of the tempered martensite is ≥50% to the whole structure, the space factor of the retained austenite is 3 to 20% to the whole structure, and also, the average crystal grain size of the retained austenite is ≤4.5 μm.
Sugimoto K et al.: "Ductility and formability of newly developed high strength low alloy TRIP-aided sheet steels with annealed martensite matrix", ISIJ international, iron and steel institute of Japan, Tokyo, JP, discloses steel sheets with annealed martensite matrix having a large amount of plate-like retained austenite along annealed martensite lath boundary.

[Disclosure of the Invention]

[Problem to be Solved by the Invention]

[0009] As mentioned above, since DP steel sheets, TRIP steel sheets, and martensite single-phase structure steel sheets have their advantages and disadvantages, a steel sheet which has high strength and excellent elongation and stretch-flanging performance at the same time is required. The present invention has been made to solve such a problem, and an object thereof is to provide a high strength steel sheet excellent in both elongation and stretch-flanging performance and a method for manufacturing the same.
[0010] Another object of the present invention is to provide a high strength steel sheet having a tensile strength of 780 MPa or higher, in which elongation and stretch-flanging performance are both improved, and a method for manufacturing the same.

[Means for Solving the Problem]

[0011] The high strength steel sheet of the present invention is constituted of, in percent by mass, C: 0.05 to 0.3%, Si: 3% or less (not including 0%.), Mn: 0.5 to 3.0%; Al: 0.01 to 0.1%, and optionally, at least an element selected from Ti, Nb, V and Zr in an amount of 0.01 to 1% in total, Ni and/or Cu in an amount of 1% or lower in total, Cr: 2% or less, Mo: 1% or less, B: 0.0001 to 0.005%, Ca and/or REM in an amount of 0.003% or lower in total, and the remainder comprising iron and inevitable impurities, has a space factor of a martensite phase which is a main part of the metal structure is 80% or higher, the mean grain size of the martensite phase is 10 μm or smaller in terms of the equivalent of a circle diameter; the space factor of the martensite phase having a grain size of 10 μm or larger in terms of the equivalent of a circle diameter in the martensite phase is 15% or lower; wherein the martensite phase is a tempered martensite phase; and the space factor of the retained austenite phase in the metal structure is 2% or lower, and the rest of the metal structure is mainly ferrite phase; and has a tensile strength of 590 MPa or higher.
[0012] To this end, the inventors of the present invention have studied various structures that can ensure high strength and improve elongation, especially stretch-flanging performance at the same time.
The term "equivalent of a circle diameter" means the diameter of an anticipated circle having the same area as the grains of tempered martensite, and is determined by subjecting a structure picture to image analysis. Moreover, the term "space factor" means the percentage by volume, and is determined by corroding a structure observation test piece with nital, observing the test piece with an optical microscope (1000 times), and by subjecting the observed structure picture to image analysis. Moreover, annealed bainite is observed as a body centered cubic structure in terms of a crystal structure. Herein, Ac_3 point is a temperature at which a two-phase region comprising an austenite phase and a ferrite phase transforms into an austenite single-phase region that is stable at high temperatures in a temperature raising step.
[0013] The inventors of the present invention have invented a high strength steel sheet having a limited ratio by volume of the retained austenite phase of 2% or lower, which does not affect stretch-flanging performance, and a metal structure in which a large part of the metal structure is a fine tempered martensite phase.
That is, in the high strength steel sheet of the present invention, the space factor of the martensite phase which is a main component of the metal structure is 80% or higher; the mean grain size of the martensite phase is 10 μm or smaller in terms of the equivalent of a circle diameter; the space factor of a martensite phase having a grain size of 10 μm or larger in terms of the equivalent of a circle diameter in the martensite phase is 15% or lower, wherein the martensite phase is a tempered martensite phase; and the space factor of the retained austenite phase in the metal structure is 2% or lower and the rest of the metal structure is mainly ferrite phase.
[0014] Herein, space factor means a ratio by volume of each phase constituting the metal structure in the steel material

to the entire metal structure. The space factors of the martensite phase and ferrite phase were determined by subjecting the steel material to repeller corrosion, observing the material by an optical microscope and an SEM (1000 times), and then subjecting the material to image analysis. The space factor of the retained austenite phase was determined by the saturation magnetization method (refer to "Netsushori" (heat treatment), Vol.136, (1996)). Moreover, the mean grain size of the martensite phase is the mean value of the crystal grain size of the martensite phase, and is determined by structure analysis using a FE/SEM-EBSP at step intervals of 100 nm in the present invention.

[0015] In the metal structure of the high strength steel sheet, the space factor of the fine tempered martensite phase having a mean grain size of 10 μm or smaller is 80% or higher, and therefore a tensile strength of 780 MPa or higher and excellent ductility are ensured. Moreover, when the space factor of the retained austenite phase is high, stretch-flanging performance is lowered. However, the space factor of the retained austenite phase is limited to 2% at the highest in the present invention, and therefore stretch-flanging performance is not lowered.

[0016] In the high strength steel sheet,
martensite phase is a tempered martensite phase.

[0017] The method for manufacturing the high strength steel sheet according to the present invention is for manufacturing a high strength steel sheet of the present invention by using a steel sheet in which the total space factor of the martensite phase and/or of the retained austenite phase in the entire metal structure is 90% or higher as a material steel sheet, heating and retaining the steel sheet at a temperature of (Ac_3 point-50°C) or higher, Ac_3 point or lower for 30 to 1200 seconds, cooling the steel sheet to a transformation start temperature of martensite, Ms point, or lower at an average cooling rate of 10°C/sec. or higher, and further conducting a heat treatment in which the steel sheet is heated and retained at a temperature of 300 to 500°C for 60 to 1200 seconds.

[0018] The high strength steel sheet according to the present invention may comprise, in addition to the above-mentioned basic components, any of the element groups (a) to (e) described below, or one or more elements selected from a plurality of groups within a range defined for each element group.

(a) an element selected from Ti, Nb, V and Zr: 0.01 to 1% by mass in total
(b) Ni and/or Cu: 1% by mass or less in total
(c) Cr: 2% by mass or less and/or Mo: 1% by mass or less
(d) 0.0001 to 0.005% by mass of B
(e) Ca and/or REM: 0.003% by mass or less in total

[Effect of the Invention]

[0019] According to the present invention, it is also possible to provide a high strength steel sheet in which the space factor of the retained austenite phase is 2% or lower and the space factor of the fine tempered martensite phase is 80% or higher by a relatively simple heat treatment step. Since this high strength steel sheet has a tensile strength of 780 MPa or higher, and also has excellent elongation and stretch-flanging performance, it is excellent in press formability.

[Best Mode for Carrying out the Invention]

(1)

[0020] The best mode for carrying out the invention will be described below in detail.
First, the composition of constituents of the high strength steel sheet material of this embodiment will be described. The elements which constitute the composition of the high strength steel sheet of this embodiment are C, Si, Mn, Al, Cr, Mo, Nb, Ti and V, and the remainder is Fe and inevitable impurities. Among these constituent elements, Cr, Mo, Nb, Ti and V are not essentially necessary constituent elements, but are the elements which are added to further increase the effect of the present invention. The actions of the elements will be described below. In the description provided below, the proportions of compositional ranges are indicated by % by mass.

[0021] Among the constituent elements mentioned above, the compositional range of C is limited within the range of 0.05% to 0.3%. C is an element effective in producing the tempered martensite phase, and increasing the strength of the steel sheet material. The lower limit value, i.e., 0.05% is an amount which is minimally necessary to obtain desired strength. The upper limit value, i.e., 0.3%, is limited for the following reason. When C is added in an amount higher than the upper limit value, 0.3%, the concentrations of C in the tempered martensite phase and the retained austenite phase are increased, and the strength of these phases is increased. A difference in strength between these phases and the ferrite phase having a low concentration of C is increased. Since rupture is likely to occur at the interface of these phases having a difference in strength, stretch-flanging performance is lowered. Meanwhile, when the concentration of C in the steel sheet is increased, weldability is significantly deteriorated.

[0022] The compositional range of Si is limited within the range higher than 0% but not higher than 3%. Si has the action to inhibit the generation of relatively coarse carbide which lowers stretch-flanging performance, and also improve ductility. However, this action to improve ductility is saturated in an amount of Si added of about 3%. Moreover, since si has the action to retard softening by tempering of the tempered martensite phase, when the amount of Si contained is high, the tempered martensite phase is not sufficiently tempered and thus strength is retained high, whereby a difference in strength between the martensite phase and the ferrite phase is increased and stretch-flanging performance is lowered. Accordingly, the upper limit of the amount of Si added is 3%.

[0023] The compositional range of Mn is limited within the range of 0.5% or higher but not higher than 3%. Mn has the effect to increase the tensile strength of the steel sheet by solid solubility reinforcement, improve the hardening characteristics of the steel sheet, and promote generation of the martensite phase. Such an action of Mn is found in steel having containing Mn in an amount of 0.5% or higher. Preferably, the amount of Mn contained is 1% or higher. In contrast, when the amount of Mn contained is higher than 3%, adverse effects such as cracks in the slab occur. The amount of Mn contained is preferably 2.5% or lower.

[0024] The compositional range of Al is limited within the range of 0.01% or higher not higher than 0.1%. Al is used for deoxidation of steel in the steelmaking process. When there is no solid solution of Al present in the metal structure of steel, deoxidation of steel may not be completed. When oxygen is remaining in steel, remaining oxygen is bonded to Si and Mn. Since these oxidation products of Si and Mn are likely to separate and float from the cast, the composition of steel becomes non-uniform and processability is lowered. Moreover, when the amount of Al solutionized in the metal structure of steel is higher than 0.1%, deoxidation products are reduced by Al again, and metal-like Al is produced. this metal-like Al serves as a relatively large mediator, and creates material defects or surface flaws. Therefore, the upper limit value of Al is 0.1%.

[0025] Cr and Mo are not elements essential to the high strength steel sheet of the embodiment, but their addition acts effectively. Cr and Mo act to inhibit the generation of carbide which lowers stretch-flanging performance, and promote the generation of the martensite phase in the metal structure of the steel sheet. Therefore, they can be added as needed. The compositional range of Cr and Mo is such that at least one or more elements selected from Cr and Mo is contained, and the total compositional ratio of these elements is 0.5% or lower. In order to effectively perform the action of Cr and Mo, it is recommended that the compositional proportions of Cr and Mo are 0.05% or higher (more preferably 0.1% or higher), respectively. However, even if Cr and Mo are added, whether singly or in combination of both, in an amount higher than 0.5%, the action mentioned above is saturated, and an action which is worth the amount of Cr and Mo contained cannot be obtained.

[0026] None of Nb, Ti and V is an element which is essential to the high strength steel sheet of this embodiment, but their addition acts effectively. Nb, Ti and V have the action to form carbonitride, increase the tensile strength of steel by enhancing deposition, and micronize crystal grains in the metal structure of the steel sheet. Accordingly, these elements are added.as needed. When the total amount added of one or more members selected from Nb, Ti and V is lower than 0.01%, the action of Nb, Ti and V mentioned above is not effective. In contrast, when the above-mentioned amount added is higher than 0.1% in total, too much precipitate is produced, and stretch-flanging performance is thus significantly lowered. Therefore, the upper limit of the total amount added mentioned above is 0.1%.

[0027] The high strength steel sheet of this embodiment may be composed to contain Ni or Cu in an amount of 1% by mass or lower in place of Cr, Mo, Nb, Ti and V. Moreover, it may be composed to contain B in an amount of 0.0001% by mass or higher but 0.0010% by mass or lower. Further, it may be composed to contain 0.003% by mass or less of Ca and/or REM in total.

[0028] The material of the high strength steel sheet of this embodiment is composed of Fe and inevitable impurities, in addition to the above-mentioned components. P and S are present as inevitable impurities, but they do not adversely affect the characteristics of the high strength steel sheet of this embodiment as long as the amount of P is 0.05% or lower (not including 0%) and the amount of S is 0.02% or lower (including 0%). The less the amount of P and S contained, the better the processability of the steel sheet. Especially, when the amount of S contained is high, MnS which serves as a mediator is increased in steel, whereby the stretch-flanging performance of the steel sheet is significantly lowered.

[0029] Second, the metal structure of the high strength steel sheet of this embodiment will be described. The metal structure of the high strength steel sheet of this embodiment comprises a tempered martensite phase having a space factor of 80% or higher and a retained austenite phase having a space factor of 2% or lower, and the rest is mainly composed of a ferrite phase.

Among these constituent phases, the tempered martensite phase will be described first. When the space factor of the tempered martensite phase is 80% or higher, combination between austenite crystal grains and growth of the same can be suppressed by the annealed martensite phase remaining finely in part of the ferrite phase after the annealing step employed in the method for manufacturing the high strength steel sheet of the embodiment described later. When the space factor of the tempered martensite phase is lower than 80%, the tempered martensite phase is divided into ferrite phases, and therefore stretch-flanging performance is lowered. In contrast, when the phase becomes a substantially single-phase structure of tempered martensite having a space factor of the tempered martensite phase of 100%, ductility is lowered. For this reason, the case where the space factor is 100% is not included in the present invention.

[0030] In the tempered martensite phase of the high strength steel sheet of this embodiment, the mean grain size is 10 μm or smaller, and the space factor of the tempered martensite phase having a grain size larger than 10 μm is 15% or lower. When the mean grain size is larger than 10μm, or when the space factor of the tempered martensite phase having a grain size larger than 10 μm is higher than 15%, the interfaces of the tempered martensite phase which act as the starting point of rupture are unevenly distributed, and therefore sufficient stretch-flanging performance cannot be obtained.

[0031] In the metal structure of the high strength steel sheet of this embodiment, the space factor of the retained austenite phase is 2% or lower. The retained austenite phase undergoes induced transformation in which it transforms into a tempered martensite phase during processing. Accordingly, the retained austenite phase lowers stretch-flanging performance. Therefore, in order to improve stretch-flanging performance, the space factor of the retained austenite phase needs to be limited to a low level. The space factor of the retained austenite phase is 2% or lower, and more preferably 1% or lower.

[0032] The high strength steel sheet of the embodiment as described above has a fine tempered martensite phase formed therein and has a sufficiently low space factor of the retained austenite phase. Hence, it has excellent characteristics: it not only has high tensile strength, but also high elongation and stretch-flanging performance at the same time.

[0033] The method for manufacturing the high strength steel sheet of this embodiment will be now described.
First, materials of the high strength steel sheet of this embodiment will be described. The high strength steel sheet of this embodiment is obtained by subjecting a steel sheet material which meets predetermined conditions to a heat treatment comprising a predetermined annealing step and a tempering step.
The steel sheet material of the high strength steel sheet of this embodiment needs to meet the conditions of the composition of constituents mentioned above and also the conditions of the following metal structure. The steel sheet material of the high strength steel sheet of this embodiment needs to have a space factor of the martensite phase and the retained austenite phase of 90% or higher. Preferably, the space factor of the martensite phase and the retained austenite phase is 95% or higher. If the space factor of these constituent phases is lower than 90%, when the steel sheet is heated to a 2-phase region of the ferrite phase and austenite phase, a coarse austenite phase is produced. Therefore, the fine tempered martensite phase mentioned above cannot be obtained. This prevents improvement in stretch-flanging performance.

[0034] The steel sheet material of the high strength steel sheet of this embodiment having a space factor of the martensite phase and the retained austenite phase of 90% or higher is produced in the manner described below.
The process for manufacturing a steel sheet material of the high strength steel sheet of this embodiment (hereinafter referred to as "steel sheet material") comprises the following steps: A steel slab adjusted to meet the composition of constituents of the high strength steel sheet material mentioned above is hot-rolled at such a temperature that the finishing rolling temperature is Ac_3 point or higher. This hot-rolled steel sheet is then cooled at a cooling rate of 10°C/sec. or higher to a cooling stop temperature, which is lower than Ms point at which the austenite phase starts to transform into the martensite phase (about 350°C or lower), and is wound up. When the finishing rolling temperature is Ac_3 point or lower or the cooling rate after the hot rolling is 10°C/sec. or lower, the ferrite phase is likely to be produced during cooling after the hot rolling, and the space factor of the low-temperature transformation phase after the hot rolling does not become 90% or higher.

[0035] Even a steel sheet produced under conditions which do not meet those of the hot rolling and cooling rate mentioned above from a steel slab adjusted to meet the composition of constituents of the steel sheet material can be modified into a steel sheet material having a space factor of its low-temperature transformation phase of 90% or higher by carrying out the following preliminary annealing. This preliminary annealing is a heat treatment in which the hot-rolled steel sheet is retained in a temperature range of Ac_3 point or higher for 5 seconds or longer, and is cooled at a cooling rate of 10°C/sec. or higher to a cooling stop temperature of 350°C or lower. When the steel sheet mentioned above is retained in a temperature range of Ac_3 point or lower, a ferrite phase is produced, and the space factor becomes no greater than 90%. Moreover, even when the steel sheet mentioned above is retained in a temperature range of Ac_3 point or higher, transformation of the metal structure into austenite is insufficient in case where the retaining time is shorter than 5 seconds, and the space factor thus becomes no greater than 90%. As long as the conditions of this preliminary annealing are met, the upper limit of the annealing temperature, retaining time and cooling rate and the lower limit of the cooling stop temperature are not specifically determined.

[0036] The heat treatment step of the high strength steel sheet of this embodiment will be described now. The high strength steel sheet of this embodiment is obtained by subjecting a steel sheet material to a heat treatment comprising a predetermined annealing step and a tempering step. This annealing step is a heat treatment in which the steel sheet material is heated to a temperature of Ac_3 point or lower but not lower than AC_3 point -50°, retained for 30 seconds or longer but not longer than 1200 seconds, and is then cooled at a cooling rate of 10°C/sec. or higher to Ms point or lower. By conducting this annealing step, the above-mentioned martensite phase having a space factor of 80% or higher is formed. Moreover, the size of austenite crystal grains produced when the steel sheet material is heated to and retained at a temperature of Ac_3 point or lower but not lower than Ac_3 point -50°affects the crystal grain size of the tempered martensite phase of the high strength steel sheet of the embodiment. That is, to obtain a fine tempered martensite having a mean grain size of 10 μm or smaller and the space factor of the tempered martensite phase having a grain size larger than 10 μm is 15% or lower phase as the high strength steel sheet of this embodiment, the steel sheet material needs to be heated to and retained at a temperature of Ac_3 point or lower but not lower than Ac_3 point -50°. A steel sheet having the metal structure in which such a fine tempered martensite phase is formed is characterized by high strength and high ductility.

In this annealing step , when the steel sheet material is retained in a temperature range higher than Ac_3 point at which the austenite single-phase is stable, crystal grains of austenite grow and combine with each other to be coarse. Therefore, the steel sheet material cannot be imparted a metal structure having a fine tempered martensite phase as the high strength steel sheet of this embodiment. As a result, the stretch-flanging performance of the high strength steel sheet is lowered. Moreover, when the steel sheet material is retained at a temperature lower than Ac_3 point -50°C, transformation into austenite does not proceed sufficiently, and the space factor of the tempered martensite phase of the high strength steel sheet after the heat treatment becomes lower than that of the high strength steel sheet of this embodiment. As a result, the stretch-flanging performance of the high strength steel sheet is lowered. Therefore, the retaining temperature was set to Ac_3 point or lower but not lower than Ac_3 point -50°C.

[0037] When the retaining time in this annealing step. is shorter than 30 seconds, the austenite phase is not sufficiently produced, and thus a fine martensite phase cannot be obtained after this annealing step. when the retaining time is longer than 1200 seconds, produced austenite crystal grains become coarse, and therefore the fine tempered martensite phase mentioned above cannot be obtained. Accordingly, the retaining time is to be in the range of 30 seconds or longer but not longer than 1200 seconds, Preferably, it is in the range of 120 seconds or longer but not longer than 600 seconds.

[0038] In this annealing step, when the cooling rate is 10°C/sec. or lower, or the cooling stop temperature is higher than Ms point at which the transformation from the austenite phase into the tempered martensite phase starts, generation of a bainite phase, retained austenite phase, pearlite phase and ferrite phase and deposition of a cementite phase are caused, and a number of phases other than the martensite phase are formed, whereby the space factor of the martensite phase cannot be increased. Accordingly, the stretch-flanging performance of the steel sheet is lowered. The higher the cooling rate, and the lower the cooling stop temperature, the higher the space factor of the tempered martensite phase can be.

[0039] The tempering step will be described now. The steel sheet material which has undergone the annealing step is retained at a temperature of 300°C to 550°C for 60 seconds to 1200 seconds. A fine martensite phase is formed in the metal structure of the steel sheet material which has undergone the annealing step. The steel sheet material is softened by tempering this martensite phase to reduce a difference in hardness from the annealed martensite phase and ferrite phase, whereby excellent stretch-flanging performance, as well as ductility, can be obtained.

[0040] When the retaining temperature in this tempering step is lower than 300°C, the hardness of the tempered martensite phase is too high, and the stretch-flanging performance of the steel sheet is thus lowered. In contrast, when the retaining temperature is higher than 550°C, the cementite phase produced by the decomposition of the retained austenite phase becomes coarse, whereby the stretch-flanging performance of the steel sheet is lowered.

When the retaining time in this tempering step is shorter than 60 seconds, the hardness of the tempered martensite phase is too high, and therefore the elongation and stretch-flanging performance of the steel sheet are lowered. In contrast, When the retaining time is longer than 1200 seconds, the cementite phase become coarse, and the stretch-flanging performance of the steel sheet is lowered. The retaining time in this tempering step is 60 seconds or longer but not longer than 1200 seconds, but it is preferably 90 seconds or longer but not longer than 900 seconds, and more preferably 120 seconds or longer but not longer than 600 seconds.

[0041] The steel sheet material which has been subjected to the annealing step and this tempering step becomes the high strength steel sheet of this embodiment, and is characterized by high stretch-flanging performance, in addition to high tensile strength and high ductility. Accordingly, this high strength steel sheet is used for various industrial products typically including automobiles as a steel sheet having excellent press formability.

(Example 1)

[0042] The actions and effects of the high strength steel sheet of this embodiment and method for manufacturing the same will be described below with reference to Examples.

First, a method for preparing test steel sheets tested in these Examples will be described. In these Examples, Steel slabs having the compositions of constituents represented by steel symbols A to Y having the compositions of constituents shown in Table 5 were tested. As shown in Table 6 and 7, 56 types of test steel sheets were prepared under different hot rolling conditions, preliminary annealing conditions, and in different annealing steps and tempering steps from the steel slabs having the compositions of constituents of these A to Y, and the tensile strength, ductility, stretch-flanging performance and other characteristics of the test steel sheets were determined. Among the steel slabs having the compositions of constituents of A to Y, B, C, E, F, I, J, L, N to Y are the steel slabs having the compositions of constituents which fall within the Examples of the embodiment. Steel slabs having other compositions of constituents do not fall within the compositions of constituents of this embodiment. As can be seen from Tables 6 and 7, the test steel sheets prepared from these steel slabs are Comparative Examples. The steel slabs having the compositions of constituents of these A to Y, respectively, were hot-rolled at a finishing temperature of 850°C to give 56 types of test steel sheets having a thickness of 3 mm (Nos.1 to 56), which were then wound up at predetermined temperatures shown in Table 6. Furthermore, the test steel sheets No.1 to 45 were washed with acid to remove scales, and were cold-rolled to a thickness of 1.2 mm. The test steel sheets excluding test steel sheets 2 and 11 were then subjected to preliminary annealing under predetermined conditions shown in Table 6. Thereafter, test steel sheets Nos.1 to 56 were subjected to the heat treatment comprising the annealing step and the tempering step under predetermined conditions shown in Table 7, and were used as test steel sheets for measurement.

[0043]

[Table 5]

Steel symbol	Chemical components (% by mass)												Transformation temperature (°C)		Remarks
	C	Si	Mn	P	S	Al	Mo	Cr	Ti	Nb	V	Others	Ac_3	Ms	
A	0.02	1.52	1.90	0.012	0.002	0.027							911	489	Comparative example
B	0.06	1.51	1.93	0.003	0.001	0.026							882	469	Example of invention
C	0.22	1.51	2.05	0.006	0.002	0.031							837	389	Example of invention
D	0.35	1.49	1.98	0.005	0.002	0.032							813	330	Comparative example
E	0.18	0.05	2.03	0.008	0.001	0.029							782	409	Example of invention
F	0.16	2.88	205	0.008	0.002	0.033							915	418	Example of invention
G	0.21	3.25	2.08	0.018	0.001	0.028							924	393	Comparative example
H	0.19	1.51	0.41	0.009	0.003	0.026							893	457	Comparative example
I	0.20	1.49	0.56	0.009	0.001	0.028							887	448	Example of invention
J	0.22	1.48	2.95	0.004	0.002	0.031							808	359	Example of invention
K	0.19	1.50	3.25	0.007	0.001	0.033							809	364	Comparative example
L	0.21	1.48	1.84	0.016	0.002	0.088							871	397	Example of invention
M	0.20	1.49	1.98	0.009	0.003	0.110							877	401	Comparative example

(continued)

Steel symbol	Chemical components (% by mass)												Transformation temperature (°C)		Remarks
	C	Si	Mn	P	S	Al	Mo	Cr	Ti	Nb	V	Others	Ac_3	Ms	
N	0.18	1.50	2.08	0.015	0.001	0.031	0.20						858	403	Example of invention
O	0.19	1.52	1.92	0.012	0.002	0.026	0.10	0.20					852	402	Example of invention
P	0.22	1.51	2.95	0.005	0.002	0.027			0.05				828	359	Example of invention
Q	0.21	1.51	2.05	0.006	0.002	0.028				0.025			838	394	Example of invention
R	0.20	1.48	1.90	0.006	0.001	0.031					0.10		855	404	Example of invention
S	0.19	1.52	210	0.008	0.001	0.031			0.05		0.05		870	402	Example of invention
T	0.20	1.47	2.04	0.015	0.003	0.027				0.024	0.05		850	399	Example of invention
U	0.18	1.49	1.99	0.009	0.002	0.048							856	409	Example of invention
V	0.17	1.43	2.03	0.011	0.003	0.051						Ni : 0.2	854	408	Example of invention
W	0.16	1.52	1.96	0.012	0.003	0.047						Cu : 0.1	863	416	Example of invention
X	0.17	1.49	2.11	0.008	0.002	0.040						B : 0.003	851	408	Example of invention
Y	0.18	1.38	1.89	0.011	0.003	0.045						Ca+REM : 0.001	855	413	Example of invention
(Note) Remainder is Fe and inevitable impurities															

[0044] As can be seen from Table 6, the steel sheets corresponding to Examples all have a space factor of the low-temperature transformation phase of 90% or higher, which falls within the conditions of the steel sheet material.

[Table 6]

Test steel sheet No.	Steel symbol	Hot-rolling conditions		Preliminary annealing conditions				Structure before annealing		Remarks
		Finishing temperature (°C)	Winding temperature (°C)	Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperature (°C)	Phase constitution	Space factor of M+ retained γ (%)	
1	A	850	500	930	120	600	20	M	100	Comparative example
2	B	850	300	-	-	-	-	α + M	85	Comparative example
3	B	850	500	930	120	600	20	M	100	Example of invention
4	C	850	500	900	120	600	20	α + M	80	Comparative example
5	C	850	500	930	120	600	20	M	100	Example of invention
6	C	850	500	930	2	600	20	α + M	80	Comparative example
7	C	850	500	930	10	600	20	α + M	90	Example of invention
8	C	850	500	930	600	600	20	M	100	Example of invention
9	C	850	500	930	120	5	20	α + M	70	Comparative example
10	C	850	500	930	120	600	500	B	0	Comparative example
11	C	850	300	-	-	-	-	α + M	95	Example of invention
12	D	850	500	930	120	600	20	M	100	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Hot-rolling conditions		Preliminary annealing conditions				Structure before annealing		Remarks
		Finishing temperature (°C)	Winding temperature (°C)	Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperature (°C)	Phase constitution	Space factor of M+ retained γ (%)	
13	E	850	500	930	120	600	20	M	100	Example of invention
14	F	850	500	930	120	600	20	M	100	Example of invention
15	G	850	500	930	120	600	20	M	100	Comparative example
16	H	850	500	930	120	600	20	M	100	Comparative example
17	I	850	500	930	120	600	20	M	100	Comparative example
18	J	850	500	930	120	600	20	M	100	Example of invention
19	K	850	500	930	120	600	20	M	100	Comparative example
20	L	850	500	930	120	600	20	M	100	Example of invention
21	M	850	500	930	120	600	20	M	100	Comparative example
22	N	850	500	930	120	600	20	M	100	Comparative example
23	N	850	500	930	120	600	20	M	100	Example of invention
24	N	850	500	930	120	600	20	M	100	Example of invention

(continued)

Test steel sheet No.	Steel symbol	Hot-rolling conditions		Preliminary annealing conditions				Structure before annealing		Remarks
		Finishing temperature (°C)	Winding temperature (°C)	Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperature (°C)	Phase constitution	Space factor of M+ retained γ (%)	
25	N	850	500	930	120	600	20	M	100	Comparative example
26	N	850	500	930	120	600	20	M	100	Comparative example
27	N	850	500	930	120	600	20	M	100	Example of invention
28	N	850	500	930	120	600	20	M	100	Example of invention
29	N	850	500	930	120	600	20	M	100	Comparative example
30	N	850	500	930	120	600	20	M	100	Comparative example
31	N	850	500	930	120	600	20	M	100	Comparative example
32	N	850	500	930	120	600	20	M	100	Comparative example
33	N	850	500	930	120	600	20	M	100	Example of invention
34	N	850	500	930	120	600	20	M	100	Example of invention
35	N	650	500	930	120	600	20	M	100	Comparative example
36	N	850	500	930	120	600	20	M	100	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Hot-rolling conditions		Preliminary annealing conditions				Structure before annealing		Remarks
		Finishing temperature (°C)	Winding temperature (°C)	Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperature (°C)	Phase constitution	Space factor of M+ retained γ (%)	
37	N	850	500	930	120	600	20	M	100	Comparative example
38	N	850	500	930	120	600	20	M	100	Example of invention
39	N	850	500	930	120	600	20	M	100	Comparative example
40	O	850	500	930	120	600	20	M	100	Example of invention
41	P	850	500	930	120	600	20	M	100	Example of invention
42	Q	850	500	930	120	600	20	M	100	Example of invention
43	R	850	500	930	120	600	20	M	100	Example of invention
44	S	850	500	930	120	600	20	M	100	Example of invention
45	T	850	500	930	120	600	20	M	100	Example of invention
46	U	900	500	930	180	700	20	M	100	Example of invention
41	V	900	500	930	120	700	20	M	100	Example of invention
48	W	900	500	930	120	700	20	M	100	Example of invention

(continued)

Test steel sheet No.	Steel symbol	Hot-rolling conditions		Preliminary annealing conditions				Structure before annealing		Remarks
		Finishing temperature (°C)	Winding temperature (°C)	Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperature (°C)	Phase constitution	Space factor of M+ retained γ (%)	
49	X	900	500	930	180	700	20	M	100	Example of invention
50	Y	900	500	930	240	700	20	M	100	Example of invention
51	U	900	250	-	-	-	-	M	100	Example of invention
52	U	950	300	-	-	-	-	M	100	Example of invention
53	U	900	200	-	-	-	-	M	100	Example of invention
54	V	920	280	-	-	-	-	M	100	Example of invention
55	W	920	300	-	-	-	-	M	100	Example of invention
56	X	920	300	-	-	-	-	M	100	Example of invention
(note) M: Martensite phase. a: Ferrite phase, B: Bainite phase, Retained y: Retained austenite phase										

[0045] As shown in Table 7, among the 56 types of test steel sheets prepared, 33 types correspond to Examples corresponding to the present embodiment, while others are Comparative Examples.

[Table 7]

Test steel sheet No.	Steel symbol	Annealing conditions				Tempering conditions		Remarks
		Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperalure (°C)	Heating temperature (°C)	Retaining time (sec.)	
1	A	880	180	600	20	450	180	Comparative example
2	B	850	180	600	20	450	180	Comparative example
3	B	850	180	600	20	450	180	Example of invention
4	C	800	180	600	20	450	180	Comparative example
5	C	800	180	600	20	450	180	Example of invention
6	C	800	180	600	20	450	180	Comparative example
7	C	800	180	600	20	450	180	Example of invention
8	C	800	180	600	20	450	180	Example of invention
9	C	800	180	600	20	450	180	Comparative example
10	C	800	180	600	20	450	180	Comparative example
11	C	800	180	600	20	450	180	Example of invention
12	D	780	180	600	20	450	180	Comparative example
13	E	750	180	600	20	450	180	Example of invention
14	F	880	180	600	20	450	180	Example of invention
15	G	880	180	600	20	450	180	Comparative example
16	H	850	180	600	20	450	180	Comparative example
17	I	850	180	600	20	450	180	Comparative example
18	J	780	180	600	20	450	180	Example of invention
19	K	780	180	600	20	450	180	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Annealing conditions				Tempering conditions		Remarks
		Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperalure (°C)	Heating temperature (°C)	Retaining time (sec.)	
20	L	850	180	600	20	450	180	Example of invention
21	M	850	180	600	20	450	180	Comparative example
22	N	900	180	600	20	450	180	Comparative example
23	N	840	180	600	20	450	180	Example of invention
24	N	820	160	600	20	450	180	Example of invention
25	N	780	180	600	20	450	180	Comparative example
26	N	820	20	600	20	450	180	Comparative example
27	N	820	50	600	20	450	180	Example of invention
28	N	820	100	600	20	450	180	Example of invention
29	N	820	1500	600	20	450	180	Comparative example
30	N	820	180	5	20	450	180	Comparative example
31	N	820	180	600	500	450	180	Comparative example
32	N	820	180	600	20	250	180	Comparative example
33	N	820	180	600	20	350	180	Example of invention
34	N	820	180	600	20	550	180	Example of invention
35	N	820	180	600	20	650	180	Comparative example
36	N	820	180	600	20	450	40	Comparative example
37	N	820	180	600	20	450	60	Comparative example
38	N	820	180	600	20	450	1000	Example of invention
39	N	820	180	600	20	450	1500	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Annealing conditions				Tempering conditions		Remarks
		Heating temperature (°C)	Retaining time (sec.)	Cooling rate (°C/sec.)	Cooling stop temperalure (°C)	Heating temperature (°C)	Retaining time (sec.)	
40	O	820	180	600	20	450	180	Example of invention
41	P	800	180	600	20	450	180	Example of invention
42	Q	800	180	600	20	450	180	Example of invention
43	R	820	180	600	20	450	180	Example of invention
44	S	850	180	600	20	450	180	Example of invention
45	T	820	180	600	20	450	180	Example of invention
46	U	840	120	700	20	500	180	Example of invention
47	V	840	120	700	20	500	180	Example of invention
48	W	850	180	300	20	400	120	Example of invention
49	X	820	120	700	20	500	180	Example of invention
50	Y	820	180	500	20	450	120	Example of invention
51	U	840	120	700	20	500	180	Example of invention
52	U	820	240	500	50	500	240	Example of invention
53	U	820	180	500	20	500	180	Example of invenlion
54	V	840	120	500	20	400	180	Example of invention
55	W	850	180	500	20	400	180	Example of invention
56	Y	820	120	500	20	400	180	Example of invention

[0046] The 56 types of the test steel sheets prepared by these steps were tested for their tensile strength and stretch-flanging performance.
The tensile strength test was performed in such a manner that the direction perpendicular to the rolling direction of each of the test steel sheets is the direction of pulling during testing by using a JIS No. 5 test piece collected from each test steel sheet according to JIS Z2241. In this test, yield strength YS, tensile strength TS and elongation EL were determined. The stretch-flanging performance test was performed according to Japan Iron and Steel Federation standard (JFST 1001-1996), and hole expansion rates λ were determined.
[0047] The measurement results of the characteristics of the 56 types of test steel sheets are shown in Tables 8 and

9. In Tables 8 and 9, AM represents an annealed martensite phase; TM represents a tempered martensite phase; and retained γ represents a retained austenite phase. The space factor of the retained austenite phase was indicated 0% when it was below the detection limit.

In the results of this test, when the tensile strength is 780 MPa or higher, it is a sufficient strength characteristic in practical use, and meets the conditions of the tensile strength of the present invention. Moreover, elongation (ductility) and stretch-flanging performance are considered excellent when they are 10% or higher and 80% or higher, respectively. The stretch-flanging performance is judged especially excellent characteristics when it is 100% or higher.

Test steel sheets which meet all the following conditions are considered to correspond to high strength steel sheets according to the present invention: tensile strength: TS≥780 MPa, elongation: EL≥10%, hole expansion rate: $\lambda \geq 80\%$. A test steel sheet which meets all these three conditions and has especially good hole expansion rate ($\lambda \geq 100\%$) was rated ◎; a test steel sheet which meets all the conditions was rated ○; a test steel sheet which meets two conditions out of three was rated Δ; and a test steel sheet which meets only one condition or less out of three conditions was rated ×.

[0048]

[Table 8]

Test steel sheet No.	Steel symbol	Metal structure parameters				Dynamic characteristics				Judgment	Remarks
		Mean grain size of TM (μm)	Space factor of TM (%)	Space factor of retained γ (%)	Space factor of TM having grain size of 10 μm or larger (%)	YS (MPa)	TS (MPa)	EL (%)	λ (%)		
1	A	6.8	89	0	8	365	608	32.2	70.1	×	Comparative example
2	B	8.8	87	0	18	523	752	28.7	82.7	Δ	Comparative example
3	B	7.0	89	0	7	598	801	26.5	122.2	◎	Example of invention
4	C	9.2	88	0	18	961	1011	8.5	61.2	×	Comparative example
5	C	6.2	88	0	11	953	1052	11.6	105.2	◎	Example of invention
6	C	11.4	88	0	20	811	1084	7.6	45.4	×	Comparative example
7	C	9.7	88	0	12	862	1098	12.1	83.4	○	Example of invention
8	C	7.0	88	0	10	873	1065	12.7	103.8	◎	Example of invention
9	C	9.8	88	0	18	795	1035	8.9	65.2	×	Comparative example
10	C	11.0	88	0	20	888	1069	8.6	75.8	×	Comparative example
11	C	8.4	88	0	12	996	1127	12	98.9	○	Example of invention
12	D	6.6	89	0	7	887	1220	11.2	76.2	Δ	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Metal structure parameters				Dynamic characteristics				Judgment	Remarks
		Mean grain size of TM (μm)	Space factor of TM (%)	Space factor of retained γ (%)	Space factor of TM having grain size of 10 μm or larger (%)	YS (MPa)	TS (MPa)	EL (%)	λ (%)		
13	E	7.6	89	0	11	778	967	13.9	90.5	○	Example of invention
14	F	6.6	89	0	8	898	1263	15.8	114.2	◎	Example of invention
15	G	8.0	87	0	8	1091	1318	10.3	67.7	Δ	Comparative example
16	H	7.2	87	6	11	932	1011	8.3	46.2	×	Comparative example
17	I	6.2	88	3	6	963	1081	10.3	89.1	○	Comparative example
18	J	7.4	90	0	8	1011	1122	11.3	81.1	○	Example of invention
19	K	6.8	90	0	11	1194	1271	7.3	48.3	×	Comparative example
20	L	7.6	91	0	7	785	823	34.7	106.4	◎	Example of invention
21	M	8.2	78	0	10	763	845	36.2	65.4	Δ	Comparative example
22	N	12.7	100	0	62	1120	1265	8.1	81.7	Δ	Comparative example
23	N	7.0	92	0	13	996	1063	12.2	88.3	○	Example of invention
24	N	8.6	88	0	11	902	1003	15.7	86.9	○	Example of invention

(continued)

Test steel sheet No.	Steel symbol	Metal structure parameters				Dynamic characteristics				Judgment	Remarks
		Mean grain size of TM (μm)	Space factor of TM (%)	Space factor of retained γ (%)	Space factor of TM having grain size of 10 μm or larger (%)	YS (MPa)	TS (MPa)	EL (%)	λ (%)		
25	N	8.4	72	0	12	855	980	17.8	58.7	△	Comparative example
26	N	7.0	62	0	9	913	969	15.2	61.7	△	Comparative example
27	N	8.0	81	0	10	909	1029	12.2	91.5	○	Example of invention
28	N	9.4	88	0	13	1056	1101	10.4	85.4	○	Example of invention
29	N	11.7	88	0	24	1101	1248	7.2	96.0	△	Comparative example
30	N	8.0	72	0	7	678	758	16.7	80.2	△	Comparative example
31	N	8.2	23	8	10	798	866	20.2	34.4	△	Comparative example
32	N	7.2	88	6	5	1229	1499	8.2	39.3	×	Comparative example
33	N	7.4	88	2	6	1129	1225	10.2	83.8	○	Example of invention
34	N	7.2	88	0	12	1078	1158	11.4	89.2	○	Example of invention
35	N	9.6	88	0	16	597	778	16.7	45.0	△	Comparative example
36	N	7.0	88	7	6	826	1205	12.3	40.6	△	Comparative example

(continued)

Test steel sheet No.	Steel symbol	Metal structure parameters				Dynamic characteristics				Judgment	Remarks
		Mean grain size of TM (μm)	Space factor of TM (%)	Space factor of retained γ (%)	Space factor of TM having grain size of 10 μm or larger (%)	YS (MPa)	TS (MPa)	EL (%)	λ (%)		
37	N	6.9	88	3	7	972	1258	10.3	85.6	○	Comparative example
38	N	7.2	88	0	7	1023	1181	11.5	91.3	○	Example of invention
39	N	10.2	88	0	17	606	798	16.5	51.6	Δ	Comparative example
40	O	6.2	89	0	7	1014	1150	12.3	86.5	○	Example of invention
41	P	6.4	90	0	6	987	1097	11.9	82.2	○	Example of invention
42	Q	6.2	88	0	6	960	983	10.3	98.3	○	Example of invention
43	R	6.4	88	0	8	936	952	10.9	96.2	○	Example of invention
44	S	6.6	92	0	8	102.3	1095	10.4	88.5	○	Example of invention
45	T	6.3	89	0	7	1008	1109	13.3	83.4	○	Example of invention

[0049]

[Table 9]

Test steel sheet No.	Steel symbol	Metal structure parameters					Dynamic characteristics			Judgment	Remarks
		Space factor of AM (%)	Mean grain size of TM (μm)	Space factor of TM (%)	Space factor of retained γ (%)	Space factor of TM having grain size of 10 μm or larger (%)	TS (MPa)	EL (%)	λ (%)		
46	a	11	8.3	89	0	10	813	31.5	108.3	◎	Example of invention
47	b	10	8.5	90	0	9	837	30.8	98.9	○	Example of invention
48	c	10	8.6	90	0	8	870	28.3	92.1	○	Example of invention
49	d	15	7.2	85	0	12	860	28.3	93.7	○	Example of Example
50	e	16	7.4	84	0	11	887	21.9	97.5	○	Example of invention
51	a	11	8.3	89	0	9	844	28.9	92.4	○	Example of invention
52	a	15	7.4	85	0	13	825	30.1	89.3	○	Example of invention
53	a	16	7.6	84	0	13	838	26.9	96.6	○	Example of invention
54	b	9	8.1	91	0	7	913	17.3	115.0	◎	Example of invention
55	c	10	8.4	90	0	8	942	15.3	109.3	◎	Example of invention
56	d	14	7.5	86	0	11	938	14.9	107.4	◎	Example of invention

[0050] The results of the measurement of test steel sheet characteristics in Table 8 will be described below.
The test steel sheets No.3, 5, 7, 8, 11, 13, 14, 18, 20, 23, 24, 27, 28, 33, 34, 38 and 40 to 45 are all prepared from steel slabs (B, C, E, F, I, J, L, N to T in Table 5) corresponding to the compositions of constituents of the high strength steel sheet of this embodiment. Moreover, as can be seen from Tables 6 and 7, the space factor of the martensite phase and the retained austenite phase of the metal structures of these test steel sheets before the annealing step, the annealing step and the tempering step correspond to the conditions of the high strength steel sheet of this embodiment. All of these test steel sheets meet the conditions of the tensile strength, elongation and stretch-flanging performance of the present invention.
[0051] The test steel sheets (Nos.46 to 56) of Table 9 all meet the conditions of the tensile strength, elongation and stretch-flanging performance of the present invention.
[0052] Among the test steel sheets which correspond to the high strength steel sheet of the embodiment, Nos. 3, 5, 8, 14 and 20 have especially good stretch-flanging performance. The space factor of the retained austenite phase of these test steel sheets is 0%. The tempered martensite phases of these test steel sheets have relatively small mean grain sizes, and the space factor of the tempered martensite phase having a crystal grain size of 10 μm or larger is relatively low.
[0053] The reason why the test steel sheets of Comparative Examples did not meet the conditions of the high strength steel sheet according to the present invention will be described.
Since the test steel sheet No-1 was prepared from steel slab A having low level of C, it has low tensile strength.
Test steel sheet No.2 had low space factors of the martensite phase and the retained austenite phase in the metal structure in a state that it is yet to be annealed were low. Therefore, crystal grains of the tempered martensite phase became coarse, and the strength and stretch-flanging performance were lowered.
Test steel sheet No.4 was subjected to the preliminary annealing at a temperature lower than Ac_3 point, and therefore the space factor of the low-temperature transformation phase in the metal structure in a state that it is yet to be annealed was lowered. This caused crystal grains of the tempered martensite phase to be coarse, whereby ductility and stretch-flanging performance are low.
[0054] The test steel sheet No.6 had low space factors of the martensite phase and the retained austenite phase in the metal structure in a state that it was yet to be annealed because the retaining time in the preliminary annealing was short, and therefore crystal grains in the tempered martensite phase became coarse. As a result, it had low elongation and stretch-flanging performance.
The test steel sheet No.9 had low space factors of the martensite phase and the retained austenite phase in the metal structure in a state that it was yet to be annealed because cooling after the preliminary annealing was delayed, and therefore the tempered martensite phase became coarse. As a result, it had low elongation and stretch-flanging performance.
The test steel sheet No.10 had low space factors of the martensite phase and the retained austenite phase in the metal structure in a state that it was yet to be annealed because the cooling stop temperature after the preliminary annealing was high, and therefore the tempered martensite phase became coarse. As a result, it had low elongation and stretch-flanging performance.
Although the test steel sheet No.12 has a metal structure after the tempering step corresponding to that of the high strength steel sheet of the embodiment, the difference in strength between the annealed martensite phase which is a part of the ferrite phase and the tempered martensite phase has not been sufficiently reduced because this test steel sheet was prepared from steel slab D having a high level of C. As a result, it had low stretch-flanging performance.
[0055] Although the test steel sheet No.15 has a metal structure after the tempering step corresponding to that of the high strength steel sheet of the embodiment, this test steel sheet was prepared from steel slab G having a high level of Si. Accordingly, the tempered martensite phase was not sufficiently tempered, and the difference in strength between the annealed martensite phase which is a part of the ferrite phase and the tempered martensite phase has not been sufficiently reduced. As a result, it had low stretch-flanging performance.
Since the test steel sheet No. 16 was prepared from steel slab H having a low level of Mn, it has insufficient hardening characteristics, and therefore a large amount of retained austenite remained after the annealing step. As a result, it had low elongation and stretch-flanging performance.
Since the test steel sheet No. 19 was prepared from steel slab K having a high level of Mn, uneven distribution of Mn occurred although the space factors and the size of the martensite phase and the retained austenite phase in the metal structure after the tempering step correspond to that of the high strength steel sheet of the embodiment. As a result, it had low elongation and stretch-flanging performance.
The test steel sheet No. 21 was prepared from steel slab M having a high amount of A1 added. Accordingly, it had a number of flaws on the surface of the steel material. As a result, it had low stretch-flanging performance.
[0056] The test steel sheet No. 22 had coarse crystal grains of the austenite phase since it was heated to a temperature higher than AC_3 point in the annealing step. As a result, its ductility was lowered.
In the test steel sheet No. 25, the austenite phase was not sufficiently produced because the heating and retaining

temperature in the annealing step was lower than Ac_3 point -50°C. As a result, it had low space factor of the tempered martensite phase, and low stretch-flanging performance.
In the test steel sheet No. 26, the austenite phase was not sufficiently produced because the retaining time at a temperature of Ac_3 point or lower but not higher than Ac_3 point -50°C in the annealing step was too short. As a result, it had low space factor of the martensite phase and low stretch-flanging performance.
In the test steel sheet No. 29, the crystal grains of the austenite phase became coarse because the retaining time at a temperature of Ac_3 point or lower but not higher than Ac_3 point -50°C in the annealing step was too long. As a result, it had large crystal grain size of the martensite phase, and low ductility.

[0057] In the test steel sheet No. 30, the tempered martensite phase was not sufficiently generated because cooling after the annealing step was too late and thus tempered phases other than the martensite phase were produced. As a result, it had low tensile strength.
In the test steel sheet No. 31, the martensite phase was not sufficiently produced because the cooling stop temperature after the annealing step was higher than Ms point. As a result, it had low space factor of the tempered martensite phase, and low stretch-flanging performance.
In the test steel sheet No. 32, the dislocation density of the tempered martensite phase was not lowered because the heating and retaining temperature in the tempering step was lower than the lower limit value, and distortion was not sufficiently mitigated. As a result, it had low elongation and stretch-flanging performance.

[0058] In the test steel sheet No. 35, cementite was deposited because the heating and retaining temperature in the tempering step was higher than the upper limit value. As a result, it had low stretch-flanging performance.
In the test steel sheet No. 36, the space factor of the retained austenite phase was not sufficiently lowered because the heating and retaining time in the tempering step was too short. Moreover, the dislocation density of the tempered martensite phase was not lowered, and distortion was not sufficiently mitigated. As a result, it had low stretch-flanging performance.
In the test steel sheet No. 39, cementite was deposited because the heating and retaining time in the tempering step was too long. As a result, it had low stretch-flanging performance.

[Industrial Applicability]

[0059] The high strength steel sheet according to the present invention has excellent elongation and stretch-flanging performance at the same time, and thus has excellent press formability. Therefore, the high strength steel sheet according to the present invention can be processed by press molding to be used for various industrial products such as automobiles, especially for industrial products where weight reduction is necessary.

Claims

1. A high strength steel sheet which comprises, in percent by mass, C: 0.05 to 0.3%; Si: 3% or less (not including 0%.); Mn: 0.5 to 3.0%; Al. 0.01 to 0.1%; and optionally, at least an element selected from Ti, Nb, V and Zr in an amount of 0.01 to 1% in total, Ni and/or Cu in an amount of 1% or lower in total, Cr: 2% or less, Mo: 1% or less, B: 0.0001 to 0.005%, Ca and/or REM in an amount of 0.003% or lower in total, and the remainder comprising iron and inevitable impurities, the high strength steel sheet having a space factor of a martensite phase which is a main part of the metal structure is 80% or higher; the mean grain size of the martensite phase is 10 μm or smaller in terms of the equivalent of a circle diameter; the space factor of the martensite phase having a grain size of 10 μm or larger in terms of the equivalent of a circle diameter in the martensite phase is 15% or lower; wherein the martensite phase is a tempered martensite phase; and the space factor of the retained austenite phase in the metal structure is 2% or lower, and the rest of the metal structure is mainly ferrite phase; and a tensile strength of 590 MPa or higher.

2. A method for manufacturing a high strength steel sheet according to claim 1, the method comprising using a steel sheet in which the total space factor of the martensite phase and/or of the retained austenite phase in the entire metal structure is 90% or higher as a material steel sheet; heating and retaining the steel sheet at a temperature of (Ac_3 point-50°C) or higher but not higher than Ac_3 point for 30 to 1200 seconds; cooling the steel sheet to a transformation start temperature of martensite, Ms point, or lower at an average cooling rate of 10°C/sec. or higher; and further conducting a heat treatment in which the steel sheet is heated and retained at a temperature of 300 to 500°C for 60 to 1200 seconds.

Patentansprüche

1. Hochfestes Stahlblech, das in Masseprozent umfasst: C: 0,05 bis 0,3 %; Si: 3 % oder weniger (ausgenommen 0 %); Mn: 0,5 bis 3,0 %; Al: 0,01 bis 0,1 %; und optional wenigstens ein Element ausgewählt aus Ti, Nb, V und Zr in einer Menge von insgesamt 0,01 bis 1 %, Ni und/oder Cu in einer Menge von insgesamt 1 % oder weniger, Cr: 2 % oder weniger, Mo: 1 % oder weniger, B: 0,0001 bis 0,005 %, Ca und/oder Seltenerdmetalle in einer Menge von insgesamt 0,003 % oder weniger, und wobei der Rest Eisen und unvermeidbare Verunreinigungen umfasst, wobei das hochfeste Stahlblech einen Raumfaktor einer Martensitphase, die ein Hauptbestandteil der Metallstruktur ist, von 80 % oder mehr aufweist; die mittlere Korngröße der Martensitphase, bezogen auf das Äquivalent eines Kreisdurchmessers, 10 μm oder weniger beträgt; wobei der Raumfaktor der Martensitphase mit einer Korngröße von 10 μm oder mehr, bezogen auf das Äquivalent eines Kreisdurchmessers, in der Martensitphase 15 % oder weniger beträgt; wobei die Martensitphase eine angelassene Martensitphase ist; und der Raumfaktor der Restaustenitphase in der Metallstruktur 2 % oder weniger beträgt, und der Rest der Metallstruktur hauptsächlich eine Ferritphase ist; und eine Zugfestigkeit von 590 MPa oder mehr.

2. Verfahren zur Herstellung eines hochfesten Stahlblechs nach Anspruch 1, wobei das Verfahren umfasst: Verwenden eines Stahlblechs, bei dem der Gesamt-Raumfaktor der Martensitphase und/oder der Restaustenitphase in der gesamten Metallstruktur 90 % oder mehr beträgt, als Material-Stahlblech; Erhitzen und Halten des Stahlblechs auf/bei eine(r) Temperatur von (Ac_3-Punkt - 50 °C) oder höher, jedoch nicht höher als der Ac_3-Punkt, für 30 bis 1200 Sekunden; Abkühlen des Stahlblechs auf eine Umwandlungsstarttemperatur von Martensit, den Ms-Punkt, oder niedriger mit einer durchschnittlichen Abkühlgeschwindigkeit von 10 °C/s oder höher; und weiterhin Durchführen einer Wärmebehandlung, bei der das Stahlblech 60 bis 1200 Sekunden lang auf/bei eine(r) Temperatur von 300 bis 500 °C erhitzt und gehalten wird.

Revendications

1. Feuille d'acier à haute résistance qui comprend, en pour cent en masse, C : 0,05 à 0,3 % ; Si : 3 % ou moins (sans inclure 0 %) ; Mn : 0,5 à 3,0 % ; Al : 0,01 à 0,1 % ; et facultativement, au moins un élément choisi parmi Ti, Nb, V et Zr dans une quantité de 0,01 à 1 % au total, Ni et/ou Cu dans une quantité de 1 % ou moins au total, Cr : 2 % ou moins, Mo : 1 % ou moins, B : 0,0001 à 0,005 % ; Ca et/ou des métaux de terres rares dans une quantité de 0,003 % ou moins au total, et le reste comprenant du fer et des impuretés inévitables, la feuille d'acier à haute résistance ayant un facteur d'espacement d'une phase de martensite qui est une partie principale de la structure métallique de 80 % ou plus ; la taille moyenne de grain de la phase de martensite est de 10 μm ou moins en termes de l'équivalent d'un diamètre de cercle ; le facteur d'espacement de la phase martensite ayant une taille de grain de 10 μm ou plus en termes de l'équivalent d'un diamètre de cercle dans la phase de martensite est de 15 % ou moins, dans laquelle la phase de martensite est une phase de martensite revenue ; et le facteur d'espacement de la phase d'austénite résiduelle dans la structure métallique est de 2 % ou moins, et le reste de la structure métallique est principalement une phase de ferrite ; et une résistance à la traction de 590 MPa ou plus.

2. Procédé de fabrication d'une feuille d'acier à haute résistance selon la revendication 1, le procédé comprenant l'utilisation d'une feuille d'acier dans laquelle le facteur d'espacement total de la phase de martensite et/ou de la phase d'austénite résiduelle dans la totalité de la structure métallique est de 90 % ou plus en tant que feuille d'acier de matériau ; le chauffage et le maintien de la feuille d'acier à une température de (point Ac_3-50 °C) ou plus mais non supérieure au point Ac_3 pendant 30 à 1200 secondes, le refroidissement de la feuille d'acier à une température de démarrage de transformation de la martensite, point Ms, ou moins à une vitesse de refroidissement moyenne de 10 °C/s ou plus ; et la réalisation en outre d'un traitement thermique dans lequel la feuille d'acier est chauffée et maintenue à une température de 300 à 500 °C pendant 60 à 1200 secondes.

REFERENCES CITED IN THE DESCRIPTION

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