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(54) **STEEL PLATE SUBJECTED TO HEAT TREATMENT AND PROCESS FOR PRODUCING THE SAME**

(57) The present invention provides a steel sheet for heat treatment consisting essentially of, by mass %, 0.05-0.09% C, below 1% Si, 1.6-2.4% Mn, 0.02% P or less, 0.02% S or less, 0.01-0.1% sol. Al, 0.005% N or less, 0.0003-0.003% B, Ti in a range satisfying $(48/32)S + (48/14)N \leq Ti \leq 2[(48/32)S + (48/14)N]$, and the rest of Fe, wherein the average diameter of iron carbides pre-

cipitating in steel is 2 μ m or smaller. The steel sheet for heat treatment according to the present invention has high strength and excellent hydrogen embrittlement resistance after being press formed and quenched, so that the steel sheet is well suited for automobile construction members.

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Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to a steel sheet for heat treatment that can be steadily imparted with high strength and excellent hydrogen embrittlement resistance by heat treatment conducted after forming process such as press forming, and a manufacturing method thereof.

BACKGROUND ART

10 **[0002]** In view of weight reduction for fuel economy and safety for cabin passengers/crews against an accident and the like, high strength steel sheets are used in a car as body construction members, reinforcing members, and various other mechanical construction components. However, the use of high strength steel sheets causes various problems such as difficulty of forming intricately shaped components, and high frequency of occurrence of brittle fracture, that is, so-called hydrogen embrittlement (delayed fracture), which is caused by hydrogen-absorption into steel from an environment.

15 **[0003]** Generally, to meet the requirement of formability and high strength, such a method as described hereunder is employed. After being formed by, for example, press forming, a steel sheet such as a cold rolled steel sheet or a hot rolled steel sheet is heated by induction-heating method or furnace-heating method, and then subjected to quenching such as water quenching, oil quenching, or press quenching. Steel sheets of several types suitable for this method have been developed in the following prior arts.

20 **[0004]** According to Japanese Examined Patent Publication No. 3-2942, there is proposed a steel sheet for precise punching which is excellent in formability in various forming modes and quench-hardenable after short time and rapid heating. The steel sheet is made of a Cr and B-added steel containing 0.10-0.19% C and 0.7-1.5% Mn.

25 **[0005]** According to Japanese Patent No. 2713382, there is proposed a method for manufacturing a high strength automobile member excellent in hydrogen embrittlement resistance. The method is characterized in that a steel containing 0.2-0.5% C, 0.5-1.6% Mn and 0.5-1.5% Cr is treated with a lubricant film forming agent, then formed, and finally subjected to quenching and tempering treatment.

30 **[0006]** According to Japanese Examined Patent Publication No. 7-103420, there is proposed a method for manufacturing a member using a B-added steel. The method is characterized in that a B-added steel containing 0.15-0.40% C and 0.60-1.50% Mn is subjected to cold press forming, then heated at a quenching temperature of 850°C to below 950°C, and water quenched at a quenching intensity of 0.35cm⁻¹ to below 1.50cm⁻¹.

35 **[0007]** According to each of Japanese Unexamined Patent Application Publications No. 5-98356 and No. 5-98357, there is proposed a method for manufacturing a Ti and B-based high carbon steel sheet having excellent formability and toughness without tempering treatment. This method is characterized in that a (Ti) and B-added steel containing 0.15-0.40% C and 0.6-1.50% Mn is used to inhibit the precipitation of cementite. Concurrently, B is added to secure hardenability, and the precipitation of AlN (and TiN) is performed to inhibit abnormal growth of austenite grains.

40 **[0008]** According to Japanese Unexamined Patent Application Publication No. 6-116679, there is proposed a method for manufacturing a steel sheet and a safety component thereof against car collision, the safety component being fabricated by press quenching. The steel sheet is manufactured in such a manner that a Ti, Nb and B-added steel containing 0.20-0.40% C and 0.20-0.40% Mn is heated at a temperature of Ac₁ to (Ac₁+30)°C for 1 to 20 hours after being hot rolled, and then cooled to a temperature below (Ac₁+30)°C at a cooling rate of 20°C/s or less. The safety component is fabricated by press quenching in the following manner. After being formed into a predetermined shape, the steel sheet is then heated to 850°C or above, cooled at a cooling rate of 80 to 150°C/s to a temperature range between 450 and 500°C while being kept in a metal die, and further cooled at a cooling rate of 20 to 100°C/s to an ordinary temperature not exceeding 100°C. Consequently, the component has a tensile strength of 1150N/mm².

45 **[0009]** According to Japanese Unexamined Patent Application Publication No. 8-269615, there is proposed a hot rolled steel sheet that can be imparted with wear resistance after being formed without impairing stretch flangeability. This is accomplished in such a manner that after being formed, the steel sheet is subjected to rapid heating such as induction quenching whereby to harden the surface without cracks. The hot rolled steel sheet consists of, by weight, 0.18-0.30% C, 0.01-1.0% Si, 0.2-1.5% Mn, 0.1-0.5% Cr, 0.0006-0.0040% B, 0.03% P or less, 0.02% S or less, 0.08% sol.Al or less, and 0.01% N or less, and balance Fe with inevitable impurities. The steel sheet has a mixed structure of ferrite and bainite.

50 **[0010]** According to Japanese Unexamined Patent Application Publication No. 10-96031, there is proposed a method for manufacturing a high carbon hot rolled steel sheet and a high carbon cold rolled steel sheet that are each excellent in ductility before being quenched and that are each capable of having a predetermined hardness and toughness after being quenched. According to the method, a Cr, Ti and B-added hot rolled steel sheet containing 0.25-0.65% C and 0.20-0.40% Mn is heated at a temperature of 650°C to below Ac₁ for 10 to 30 hours, or is slowly cooled to (Ac₁-30)°C

at a cooling rate of 3 to 20°C/h or to (Ac₁-20)°C at a cooling rate of 3 to 10°C/h after being heated at a temperature of Ac₁ to (Ac₁+30)°C for 1 to 20 hours, followed, by necessary, by being cold rolled at a reduction rate of 30 to 70% and heated at a temperature of 650°C to below Ac₁ for 20 seconds or more.

[0011] According to Japanese Unexamined Patent Application Publication No. 10-147816, there is proposed a method for manufacturing a high carbon steel sheet that is excellent in formability and that is capable of having sufficient strength after being formed and heat treated. The method is characterized in that a Cr, Ti and B-added steel containing 0.25-0.45% C and 0.2-0.5% Mn is hot rolled, coiled at a temperature between 550 and 600°C, pickled, heated in an atmosphere of 95vol.% or more of hydrogen at a temperature between Ac₁ and (Ac₁+30)°C for 1 to 10 hours, slowly cooled to (Ar₁-50)°C or less at a cooling rate of 3 to 20°C/h. Alternatively, the steel sheet is further cold rolled and annealed at a temperature of (Ac₁-10)°C or less.

[0012] According to Japanese Unexamined Patent Application Publication No. 10-251757, there is proposed a method for manufacturing a high carbon steel sheet that is excellent in formability and that is capable of having sufficient strength through a post forming heat treatment. The method is characterized in that a Cr, Ti and B-added steel containing 0.25-0.45% C and 0.2-0.5% Mn is hot rolled at a finishing temperature between (Ar₃+20) and (Ar₃+50)°C, coiled at a temperature between 550 and 600°C, pickled, heated in an atmosphere of 95vol.% or more of hydrogen at a temperature between Ac₁ and (Ac₁+30)°C for 1 to 10 hours, and slowly cooled to (Ar₁-50)°C or less at a cooling rate of 3 to 20°/h.

[0013] According to Japanese Unexamined Patent Application Publication No. 10-60522, there is proposed a steel sheet having excellent formability that can be imparted with sufficiently high strength through melting and rapid solidification using high density energy irradiation such as laser irradiation. The steel sheet is characterized by comprising 0.04-0.3% C and 3% Mn or less, and by receiving high density energy irradiation for a time that satisfies a predetermined formula, the bead pitch of high density energy irradiation being larger than 1mm.

[0014] According to Japanese Unexamined Patent Application Publication No. 2000-144319, a steel sheet and a manufacturing method therefor are proposed, the steel sheet having sufficient formability adaptable for body construction members of car and high strength through post forming quenching. The steel sheet is made of a Ti and B-added steel containing 0.05-0.20% C, 0.8-2.0% Mn, and Ti in a range of 3.4×N(%) or less. The steel sheet is manufactured in such a manner that a steel slab having the aforementioned composition is hot rolled, and coiled at a coiling temperature of 600°C or above. Alternatively, the hot rolled steel sheet is coiled at a coiling temperature of 480°C or above, followed by being cold rolled and annealed.

[0015] However, the above prior arts have problems described hereunder.

[0016] In Patent Publication No. 3-2942, since the C content is high, hydrogen embrittlement resistance after quenching is not excellent. In addition, since the Mn content is as low as 0.7-1.5%, high strength after quenching can not be steadily obtained.

[0017] In Patent No. 2713382, since the C content is high, hydrogen embrittlement resistance after quenching is not excellent. Since the Mn content is as low as 0.5-1.6%, high strength after quenching can not be steadily obtained. Further, since tempering is essentially required, manufacturing cost (heat treatment cost) is increased.

[0018] Similar problems arise in any of Japanese Examined Patent Publication No. 7-103420 and Japanese Unexamined Patent Application Publications No. 5-98356, No. 6-116679, No. 8-269615, No. 10-96031, No. 10-147816, and No. 10-251757. That is, since the C content is high, hydrogen embrittlement resistance is not sufficient, and since the Mn content is low, high strength after quenching can not be steadily obtained.

[0019] In Japanese Examined Patent Publication No. 10-60522, in the quenching by high density energy irradiation such as laser irradiation, heating is performed restrictively to a narrow linear range. As such, high strength is given to a limited portion, and thus high strength of the overall component can not be obtained. Further, since the bead pitch in the linearly heated portion is required to be larger than 1mm, the entire surface cannot be uniformly quenched.

[0020] In Patent Publication No. 2000-144319, the C and Mn content ranges are so wide that high strength after quenching can not be steadily obtained. Excellent hydrogen embrittlement resistance can not be obtained either.

DISCLOSURE OF THE INVENTION

[0021] An object of the present invention is to provide a steel sheet for heat treatment that can be steadily imparted with high strength and excellent hydrogen embrittlement resistance by heat treatment conducted after forming process such as press forming, and a manufacturing method thereof.

[0022] The object is achieved by providing a steel sheet for heat treatment consisting essentially of, by mass %, 0.05-0.09% C, 1% Si or less, 1.6-2.4% Mn, 0.02% P or less, 0.02% S or less, 0.01-0.1% sol.Al, 0.005% N or less, 0.0003-0.003% B, Ti satisfying formula (1), and the balance of Fe, wherein the average diameter of iron carbides precipitating in the steel is 2μm or smaller.

$$(48/32)S+(48/14)N \leq Ti \leq 2[(48/32)S+(48/14)N] \quad (1)$$

[0023] In formula (1), each element symbol represents the content of each element, by mass %.

[0024] A steel sheet for heat treatment according to the present invention can be manufactured by a method comprising the steps of: hot rolling a steel slab having the aforementioned composition into a steel sheet; cooling the hot rolled steel sheet at an average cooling rate of 30°C/s or less; and coiling the cooled hot rolled steel sheet at a coiling temperature of 500°C or above.

EMBODIMENTS OF THE INVENTION

[0025] The present inventors conducted study and research on a steel sheet that can be steadily imparted with high strength and excellent high hydrogen embrittlement resistance by heat treatment conducted after forming process such as press forming. Consequently, it is found that reduction in C content, addition of B, and control of iron carbides are effective. This will be described in more detail below.

1. Composition

[0026] C: C is an important element to enhance strength of steel sheet by heat treatment. C should be added in an amount of 0.05% or more to impart sufficiently high strength to steel sheet. On the other hand, however, when C content exceeds 0.09%, hydrogen embrittlement resistance after heat treatment is deteriorated. In view of these facts, C content is specified to 0.05-0.09%.

[0027] Si: Si can be appropriately added by necessity. However, Si content exceeding 1% not only deteriorates chemical conversion treatability, but also leads to an increase in manufacturing cost. In view of these facts, Si content is specified to 1% or less.

[0028] Mn: Mn is an essential element to steadily impart high strength independently of heat treatment conditions such as soaking temperature, holding time and cooling rate. Mn content less than 1.6% can not sufficiently stabilize hardenability of steel sheet; and on the other hand, Mn content exceeding 2.4% deteriorates press formability of steel sheet. For these reasons, Mn content is specified to 1.6-2.4%.

[0029] P: P is an impurity in steel. P content exceeding 0.02% deteriorates formability and weldability of steel sheet, so that P content is specified to 0.02% or less. Although P should be preferably removed as much as possible in steelmaking process, too much reduction of P content leads to an increase in manufacturing cost.

[0030] S: S is an impurity in steel. S content exceeding 0.02% deteriorates formability and weldability of steel sheet, so that S content is specified to 0.02% or less. Although S should be preferably removed as much as possible in steelmaking process, too much reduction of S content leads to an increase in manufacturing cost.

[0031] Sol.Al: Al is added as a deoxidizing agent and for precipitating N in the form of AlN. While sol.Al content less than 0.01% is not sufficiently effective, sol.Al content exceeding 0.1% saturates the effect, leading to an increase in manufacturing cost. For these reasons, sol.Al content is specified to 0.01-0.1%.

[0032] N: N is an impurity in steel. N content exceeding 0.005% deteriorates formability of steel sheet, so that N content is specified to 0.005% or less. Although N should be preferably removed as much as possible in steelmaking process, too much reduction of N content leads to an increase in manufacturing cost.

[0033] Ti: Ti combines with N in the form of TiN and thus prevents B from precipitating in the form of BN whereby enhancing the effect of B. Ti generates sulfides while a steel slab is being cooled after heating in advance of nitrides generation, so that, to completely delete solute N, Ti should be added in an amount greater than or equal to the atomic equivalents of N and S, that is, greater than or equal to $(48/32)S+(48/14)N$. On the other hand, however, when Ti is excessively added in an amount exceeding twice the atomic equivalents, TiC precipitates, so that the formability of steel sheet is deteriorated. For these reasons, Ti content is specified to the range of from $(48/32)S+(48/14)N$ to $2[(48/32)S+(48/14)N]\%$.

[0034] B: B should exist in the form of solute B in steel so as to steadily obtain high strength independently of heat treatment conditions such as soaking temperature, holding time and cooling rate. B content less than 0.0003% does not sufficiently exhibit this effect. On the other hand, B content exceeding 0.003% not only saturates the effect of B, but also reduces productivity in steel sheet manufacturing process. For these reasons, B content is controlled to 0.0003 to 0.003%.

[0035] The strength enhancement of steel sheet can be more steadily implemented when at least one element selected from 0.1-2% Cr and 0.1-2% Mo is added in addition to the composition described above. The content of Cr and Mo is each specified to 0.1-2% for the reason that the content of 0.1% or less is insufficient to steadily implement the strength enhancement, whereas the content exceeding 2% deteriorates the formability of steel sheet.

[0036] While the rest is essentially Fe, small amounts of inevitable impurities and other elements may be included

within a range that does not disturb the advantage of the present invention.

2. Iron carbides

[0037] The average diameter of iron carbides precipitating in steel influences the dissolution of the iron carbides at heat treatment. The average diameter should be controlled to $2\mu\text{m}$ or smaller so that the iron carbides can be dissolved into austenite in a very short time, leading to high strength after quenching.

3. Manufacturing method

[0038] The steel sheet for heat treatment of the present invention can be manufactured by a method for manufacturing a steel sheet for heat treatment comprising the steps of: hot rolling a steel slab having the above-described composition into a steel sheet; cooling the hot rolled steel sheet at an average cooling rate of 30°C/s or less; and coiling the cooled steel sheet at a coiling temperature of 500°C or higher.

[0039] In the above, the hot rolled steel sheet is cooled at the average cooling rate of 30°C/s or less for the reason that an average cooling rate exceeding 30°C/s generates second phases that deteriorate the formability of steel sheet. For the same reason, the coiling temperature is set to 500°C or higher.

[0040] Alternatively, the steel sheet for heat treatment of the present invention can be manufactured by a method for manufacturing a steel sheet for heat treatment comprising the steps of: hot rolling a steel slab having the above-described composition into a steel sheet; cold rolling the hot rolled steel sheet; and annealing the cold rolled steel sheet for recrystallization, wherein the annealed steel sheet is cooled at an average cooling rate of 30°C/s or less to 400°C .

[0041] In the above, the annealed steel sheet is cooled at the average cooling rate of 30°C/s or less to 400°C for the reason that generation of second phases is inhibited not to deteriorate the formability of steel sheet.

[0042] In the present invention, heating temperature of steel slab prior to hot rolling should be preferably controlled to $1200\text{--}1250^\circ\text{C}$ from the viewpoint of enhancing the formability. Finishing temperature at hot rolling should be preferably controlled to $\text{Ar}_3\text{--}890^\circ\text{C}$ from the viewpoint of making the ferrite structure to be uniform and fine. When improving flatness of hot rolled steel sheet and deleting yield point elongation to enhance formability of hot rolled steel sheet, temper rolling should be preferably conducted at an elongation rate of $0.3\text{--}1.5\%$ after coiling.

[0043] Even when manufacturing a cold rolled steel sheet, the above-described hot rolling conditions, that is, the slab heating temperature controlled to $1200\text{--}1250^\circ\text{C}$ and the finishing temperature controlled to $\text{Ar}_3\text{--}890^\circ\text{C}$, should be preferably taken from the same viewpoint. Further, also the cooling rate after hot rolling should be preferably controlled to 30°C/s or less for a reason that when the average cooling rate from hot rolling final pass to coiling exceeds 30°C/s , second phases are generated whereby to reduce manufacturability.

[0044] Reduction rate at cold rolling should be preferably controlled to 60% or greater to obtain fine iron carbides having an average diameter of $2\mu\text{m}$ or smaller, which are essential to the present invention. From the viewpoint of formability, annealing temperature should be preferably controlled to $670\text{--}720^\circ\text{C}$ at box annealing and to $690\text{--}730^\circ\text{C}$ or $800\text{--}850^\circ\text{C}$ at continuous annealing. When improving flatness of cold rolled steel sheet and deleting yield point elongation to enhance formability of cold rolled steel sheet, temper rolling should be preferably conducted at an elongation rate of $0.3\text{--}1.5\%$ after annealing.

EXAMPLE 1

[0045] Slabs were cast after vacuum melting of steels 1-14 having composition shown in Table 1. After reheated at 1250°C , the slabs were each hot rolled at a finishing temperature of 870°C into hot rolled steel sheets. The hot rolled steel sheets were each cold rolled to 1.2mm , and subjected to $720^\circ\text{C} \times 2\text{min.}$ annealing simulating continuous annealing. Thus produced cold rolled steel sheets 1-14 were cooled at an average cooling rate of 10°C/s , and temper rolled at an elongation rate of 1.5% . Further, the cold rolled steel sheets 13 and 14 were each heat treated at 600°C to control the carbide diameter.

[0046] JIS No. 5 tensile test pieces were taken from the cold rolled steel sheets in the direction rectangular to the rolling direction (i.e., width direction) to measure mechanical properties.

[0047] Then, for these cold rolled steel sheets, tensile strengths were measured after quenching performed under the following three conditions:

Condition 1: Water quenching after $1000^\circ\text{C} \times 5\text{min.}$ heating

Condition 2: Water quenching after $1000^\circ\text{C} \times 5\text{min.}$ heating and air cooling to 800°C

Condition 3: Water quenching after $900^\circ\text{C} \times 5\text{sec.}$ heating

[0048] Condition 1 is an ideal solution treatment and quenching condition. Condition 2 is a condition for delayed quenching after solution treatment. Condition 3 is a condition simulating low temperature and short time solution treatment such as quenching after induction-heating. For a steel sheet for heat treatment according to the present invention, it is preferable that high strength can be steadily obtained after quenching under any of the conditions 1 to 3.

[0049] Further, 30×100mm rectangular test pieces were cut out from the cold rolled steel sheets quenched under the condition 1, and bent to 180° at a radius of 10mmR, being U-shaped. Then, the U-shaped test pieces were tightened with bolts at both ends of the test piece by a force corresponding to spring back, and immersed into a 0.1N hydrochloric acid solution to measure time until cracking occurs. In this manner, the hydrogen embrittlement resistance was investigated. A criterion for excellent hydrogen embrittlement resistance is no crack occurring in at least 30 days (delayed fracture time: at least 30 days).

[0050] Table 2 shows mechanical properties, tensile strengths after quenching, and delayed fracture time.

[0051] Any of steel sheets 2, 7, and 11 to 13 has a high ductility (EI) leading to excellent formability, a tensile strength of 1200MPa or higher after quenching independently of the quenching conditions, and 30 days or longer delayed fracture time leading to excellent hydrogen embrittlement resistance.

[0052] In comparison, steel sheet 1 of comparative example has C content less than the present invention range, so that the tensile strength after quenching is insufficient. Steel sheet 3 has C content greater than the invention range, so that the delayed fracture time is as short as three days resulting in poor hydrogen embrittlement resistance. In addition, the sheet 3 has an average carbide diameter exceeding 2μm, so that the tensile strength after quenching is insufficient at low temperature and short time solution treatment under the condition 3. Steel sheet 4 has Mn content less than the invention range, so that the tensile strength after quenching is insufficient under the condition 2. Steel sheet 5 has Mn content greater than the invention range, so that the ductility is low, hence offering poor formability. Steel sheet 6 has Ti content less than the invention range, so that the tensile strength after quenching is insufficient under the condition 2. Steel sheet 8 has Ti content greater than the invention range, so that the steel sheet has low ductility, hence offering poor formability. Steel sheet 9 has B content less than the invention range, so that the steel sheet has insufficient tensile strength after quenching under the condition 2. Steel sheet 10 has B content greater than the invention range, so that the steel sheet has low ductility, hence offering poor formability. Steel sheet 14 has an average carbide diameter exceeding 2μm, so that the steel sheet has insufficient tensile strength at low temperature and short time heat treatment under the condition 3.

TABLE 1

Steel	Chemical composition (mass %)											(48/32)S+ (48/14)N	2[(48/32)S+ (48/14)N]	Remarks
	C	Si	Mn	P	S	sol.Al	N	Ti	B	Cr	Mo			
1	<u>0.035</u>	0.03	2.0	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
2	0.065	0.03	1.9	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Inventive example
3	<u>0.125</u>	0.03	1.6	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
4	0.085	0.03	<u>1.5</u>	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
5	0.065	0.03	<u>2.7</u>	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
6	0.065	0.03	1.8	0.015	0.008	0.045	0.025	<u>0.012</u>	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
7	0.075	0.03	1.7	0.015	0.008	0.045	0.025	0.031	0.0010	<0.01	<0.01	0.021	0.041	Inventive example
8	0.065	0.03	2.1	0.015	0.008	0.045	0.025	<u>0.050</u>	0.0010	<0.01	<0.01	0.021	0.041	Comparative example
9	0.073	0.03	1.8	0.015	0.008	0.045	0.025	0.025	<u>0.0002</u>	<0.01	<0.01	0.021	0.041	Comparative example
10	0.063	0.03	2.0	0.015	0.008	0.045	0.025	0.025	<u>0.0050</u>	<0.01	<0.01	0.021	0.041	Comparative example
11	0.065	0.03	1.7	0.015	0.008	0.045	0.025	0.022	0.0010	0.50	<0.01	0.021	0.041	Inventive example
12	0.065	0.03	1.8	0.015	0.008	0.045	0.025	0.027	0.0010	<0.01	0.30	0.021	0.041	Inventive example
13	0.065	0.03	2.0	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Inventive example
14	0.073	0.03	1.9	0.015	0.008	0.045	0.025	0.025	0.0010	<0.01	<0.01	0.021	0.041	Comparative example

Underline: Outside of Present Invention Range

TABLE 2

Steel sheet	Steel	Average carbide diameter (μm)	Mechanical properties			Tensile strength after quenching (MPa)			Delayed fracture (hydrogen embrittlement) time	Remark
			YP (MPa)	TS (MPa)	El (%)	Condition 1	Condition 2	Condition 3		
1	1	0.5	301	429	34.9	965	936	946	30 days or longer	Comparative example
2	2	0.8	309	442	33.9	1295	1256	1269	30 days or longer	Inventive example
3	3	3.5	314	448	33.5	1432	1389	960	3 days	Comparative example
4	4	0.9	299	427	35.1	1288	940	1262	30 days or longer	Comparative example
5	5	0.8	349	498	28.0	1525	1521	1494	30 days or longer	Comparative example
6	6	0.7	305	435	34.5	1266	960	1241	30 days or longer	Comparative example
7	7	0.5	305	435	34.5	1291	1253	1266	30 days or longer	Inventive example
8	8	0.8	340	485	29.0	1352	1312	1325	30 days or longer	Comparative example
9	9	0.7	308	441	34.0	1239	955	1214	30 days or longer	Comparative example
10	10	0.7	322	460	29.5	1320	1280	1294	30 days or longer	Comparative example
11	11	0.7	300	428	35.0	1358	1317	1331	30 days or longer	Inventive example
12	12	0.8	305	435	34.5	1320	1280	1294	30 days or longer	Inventive example
13	13	1.5	314	449	33.4	1324	1284	1234	30 days or longer	Inventive example
14	14	3.1	313	447	33.5	1338	1298	975	30 days or longer	Comparative example

Underline: Outside of Present Invention Range

EXAMPLE 2

[0053] By using the steels 2 and 7 shown in Table 1, steel sheets A to G were manufactured under manufacturing

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conditions shown in Table 3. For these steel sheets, quenching under the conditions similar to those in EXAMPLE 1 was conducted, and measurements similar thereto were conducted. The results are shown in Table 4.

[0054] Any of steel sheets A, D, E, and F has high ductility (EI) leading to excellent formability, tensile strength of 1200MPa or higher after quenching independently of the conditions, and 30 days or longer delayed fracture time leading to excellent hydrogen embrittlement resistance.

[0055] In comparison, steel sheets Band C (comparative examples) each have low ductility, hence offering poor formability. This is because the steel sheet B received rapid cooling not only after hot rolling but also after continuous annealing, and the steel sheet C received low temperature coiling after hot rolling.

TABLE 3

Steel sheet	Steel	Hot rolling conditions			Cold reduction rate (%)	Annealing conditions			Remarks
		Heating temperature (°C)	Finishing temperature (°C)	Cooling rate (°C/s)		Coiling temperature (°C)	Soaking temperature (°C)	Holding time	
A	2	1230	880	20	-	600	-	-	Inventive example
B	2	1230	870	35	-	600	-	-	Comparative example
C	2	1230	860	20	-	450	-	-	Comparative example
D	7	1230	870	20	60	600	700	2 minutes	Inventive example
E	7	1230	870	20	60	600	830	2 minutes	Inventive example
F	7	1230	870	20	60	600	690	2 hours	Inventive example
G	7	1230	870	20	60	600	720	2 minutes	Comparative example

Underline: Outside of Present Invention Range

TABLE 4

Steel sheet	Mechanical properties			Tensile strength after quenching (MPa)			Delayed fracture (hydrogen embrittlement) time	Remark
	YP (MPa)	TS (MPa)	El (%)	Condition 1	Condition 2	Condition 3		
A	309	442	33.9	1295	1256	1269	30 days or longer	Inventive example
B	357	510	29.4	1320	1280	1294	30 days or longer	Comparative example
C	387	553	27.1	1273	1235	1248	30 days or longer	Comparative example
D	302	432	34.7	1280	1242	1254	30 days or longer	Inventive example
E	295	421	35.6	1260	1521	1235	30 days or longer	Inventive example
F	279	399	37.6	1265	1227	1240	30 days or longer	Inventive example
G	352	503	29.8	1291	1253	1266	30 days or longer	Comparative example

Claims

1. A steel sheet for heat treatment consisting essentially of, by mass %, 0.05-0.09% C, below 1% Si, 1.6-2.4% Mn, 0.02% P or less, 0.02% S or less, 0.01-0.1% sol.Al, 0.005% N or less, 0.0003-0.003% B, Ti satisfying formula (1), and the rest of Fe:

$$(48/32)S + (48/14)N \leq Ti \leq 2[(48/32)S + (48/14)N] \quad (1)$$

(the content of each element shown by the element symbol in formula (1) is represented by mass %), wherein the average diameter of iron carbides precipitating in steel is 2 μ m or smaller.

2. The steel sheet for heat treatment according to claim 1, further comprising at least one element selected from 0.1-2% Cr and 0.1-2% Mo.

3. A method for manufacturing a steel sheet for heat treatment comprising the steps of:

hot rolling a steel slab having composition as defined in claim 1 or 2 into a steel sheet;
cooling the hot rolled steel sheet at an average cooling rate of 30°C/s or less; and
coiling the cooled steel sheet at a coiling temperature of 500°C or above.

4. A method for manufacturing a steel sheet for heat treatment comprising the steps of:

hot rolling a steel slab containing composition defined in claim 1 or 2 into a steel sheet;
cold rolling the hot rolled steel sheet; and
annealing the cold rolled steel sheet for recrystallization,

wherein the annealed cold rolled steel sheet is cooled at an average cooling rate of 30°C/s or less to 400°C after annealing.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/02300

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ C22C38/00, B21B3/00

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)
Int.Cl⁷ C22C38/00, B21B3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2003
Kokai Jitsuyo Shinan Koho 1971-2003 Jitsuyo Shinan Toroku Koho 1996-2003

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-178684 A (Nippon Steel Corp.), 27 June, 2000 (27.06.00), (Family: none)	1-4
A	JP 8-73985 A (Nippon Steel Corp.), 19 March, 1996 (19.03.96), (Family: none)	1-4

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

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27 May, 2003 (27.05.03)

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Name and mailing address of the ISA/
Japanese Patent Office

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