US 20060219333A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2006/0219333 A1

Samamoto et al. (43) Pub. Date: Oct. 5, 2006

(54) MANUFACTURING METHOD OF SEAMLESS STEEL PIPE FOR MECHANICAL STRUCTURAL PARTS

(76) Inventors: **Makoto Samamoto**, Naga-Gun (JP); **Katsunori Nagao**, Wakayama-Shi (JP)

Correspondence Address:
CLARK & BRODY
1090 VERMONT AVENUE, NW
SUITE 250
WASHINGTON, DC 20005 (US)

(21) Appl. No.: **11/393,801**

(22) Filed: **Mar. 31, 2006**

(30) **Foreign Application Priority Data**

Mar. 31, 2005 (CN) 200510059860.3

Publication Classification

(51) **Int. Cl.**
C21D 9/08 (2006.01)

(52) **U.S. Cl.** **148/593**; 148/653

(57) **ABSTRACT**

The present invention provides a manufacturing method of seamless steel pipe for mechanical structural parts. According to this manufacturing method, production process is simplified and production cost is reduced by employing inline quenching, and simultaneously, the toughness of steel pipe is guaranteed by controlling Ti/N to be 3.5 or lower. A manufacturing method of seamless steel pipe, in which steel having the chemical composition: by weight percent, 0.10 to 0.25% of C, not greater than 1.00% of Si, 0.20 to 2.00% of Mn, not greater than 0.03% of P, not greater than 0.020% of S, 0.10 to 1.5% of Cr, not greater than 0.5% of Mo, 0.005 to 0.030% of Ti, 0.01 to 0.10% of V, and the balance being Fe and incidental impurities, and Ti/N being 3.5 or lower, is subjected to finish rolling at temperature of 900° C. or higher and the section-decrease rate of 40% or greater; then subjected to soaking directly at temperature of 900 to 1000° C. without cooling, and then quenching and tempering.

MANUFACTURING METHOD OF SEAMLESS STEEL PIPE FOR MECHANICAL STRUCTURAL PARTS

TECHNICAL FIELD

[0001] The present invention relates to a manufacturing method of seamless steel pipe, especially a manufacturing method of seamless steel pipe for mechanical structural parts.

BACKGROUND ART

[0002] Conventionally, in order to ensure the strength and toughness of grade 60K and 80K steel pipe used for cylinders, offline quenching process is employed hitherto. However, it causes long production period and high manufacturing cost.

DISCLOSURE OF INVENTION

[0003] An object of the present invention is to provide a manufacturing method of seamless steel pipe for mechanical structural parts. According to this manufacturing method, production process is simplified and production cost is reduced by employing inline quenching, and simultaneously, the toughness of steel pipe is guaranteed by controlling Ti/N to be 3.5 or lower. In order to obtain this object, the manufacturing method of seamless steel pipe for mechanical structural parts according to the present has the following aspects.

[0004] (1) A manufacturing method of seamless steel pipe, in which, steel having the chemical composition: by weight percent, 0.10 to 0.25% of C, not greater than 1.00% of Si, 0.20 to 2.00% of Mn, not greater than 0.03% of P, not greater than 0.020% of S, 0.10 to 1.5% of Cr, not greater than 0.5% of Mo, 0.005 to 0.030% of Ti, 0.01 to 0.10% of V, and the balance being Fe and inevitable impurities, and Ti/N being 3.5 or lower, is subjected to finish rolling at temperature of 900° C. or higher and the section-decrease rate of 40% or greater; then subjected to soaking directly at temperature of 900 to 1000° C. without cooling, and then quenching and tempering.

[0005] (2) A manufacturing method of seamless steel pipe according to (1), wherein the chemical composition of the steel used therein further comprises one or more components selected from C: not greater than 0.5%, Ni: not greater than 1.0% and Nb: not greater than 0.01%.

[0006] Reasons for limiting the chemical composition of the steel used in the manufacturing method of seamless steel pipe for mechanical structural parts according to the present invention are specified below.

	Content Range	Reasons for Limiting
C	0.10 to 0.25%	C is an indispensable element for ensuring quenching. However, if the C content is less than 0.10%, the effect is not sufficient. On the other hand, if the C content exceeds 0.25%, crack in quenching, reduction of toughness, deterioration of weldability and machining ability of product would happen. Therefore, the C content is defined within a range of 0.10 to 0.25%. Further, due to the decrease of alloy elements with the strength improvement, the content C may be defined to 0.16% or great.
Si	Not greater than 1.00%	Si is an effective element for deoxidizing and improving strength of steel. However, if Si content exceeds 1.0%, excessive Si would make steel fragile. In order to ensure excellent toughness, the Si content is controlled at not greater than 1.0%.
Mn	0.20 to 2.00%	Mn is an indispensable element for deoxidizing and desulfurizing of steel, and also effective for ameliorating strength and heat machining ability and obtaining suitable structure. If the Mn content is less than 0.2%, such effects are not sufficient. Furthermore, if the Mn content exceeds 2.0%, although the strength is improved, the weldability and machining ability would be deteriorated. Therefore, the Mn content is defined within a range of 0.2 to 2.0%.
P	Not greater than 0.030%	P exists in steel as an inevitable impurity. If the P content exceeds 0.030%, boundary of crystal grains will be segregated to deteriorate the toughness. Therefore, the P content is controlled at not greater than 0.030%.
S	Not greater than 0.020%	S, similar to P, exists in steel as an inevitable impurity. Since S would form coarse inclusion, especially brings deterioration of toughness in the rolling direction and right-angle (T direction) of steel. Therefore, S content is controlled at not greater than 0.020%.
Cr	0.10 to 1.5%	Cr, similar to C, is an indispensable element for ensuring quenching. However, If the Cr content is less than 0.1%, its effect would be insufficient. On the other hand, if the Cr content exceeds 1.5%, the weldability and machining ability would be decreased. Therefore, the Cr content is defined within a range of 0.1 to 1.5%.
Mo	Not greater than 0.5%	Mo is an indispensable element for ensuring toughness by quenching and tempering at high temperature. However, if the Mo content exceeds 0.5%, such effects become saturated, while the machining ability of pipe-making is degrade due to the segregation. Therefore, the Mo content is controlled at not greater than 0.5%.
Ti	0.005 to 0.030%	Ti is an element for refining the crystal grains to improve toughness. However, if the Ti content is less than 0.005%, Its effect would be insufficient. On the other hand, if the Ti content exceeds 0.030%, excessive addition would form coarse carbides to degrade the toughness. Therefore, the Ti content is defined within a range of 0.005 to 0.030%.
V	0.01 to 0.10%	V is an element for improving the toughness by tempering at high temperature. However, if the V content is less than 0.01%, its effect would be insufficient. On the other hand, if the V content exceeds 0.10%, the excessive addition would form coarse carbides to degrade the toughness. Therefore, the V content is defined within a range of 0.01 to 0.10%.
Ti/N	Not greater than 3.5	The excessive addition of Ti would form TiC precipitated to deteriorate steel. TiN formed by the combination of Ti and N is effective to suppress the precipitation of TiC. Therefore, if the atomic weight ratio of Ti/N is controlled at not greater than 3.5, the precipitation of TiC can be suppressed.

[0007] By limiting the chemical composition of the steel used in the present invention to the above-stated ranges, the seamless steel pipe for mechanical structural parts with refined crystal grains and excellent toughness and strength can be obtained. If further improvements of crystal grain refinement, toughness and strength of steel are required, one or more elements of Ni, Cu and Nb may be added to the chemical composition described above. The reasons for limiting the addition of these elements are described as follows.

Ni	Not greater than 1.0%	Ni is an effective element for ameliorating quenching and improving toughness. However, at the viewpoint of cost, the Ni is an expensive alloy element, so that the Ni content is controlled at not greater than 1.0%.
Cu	Not greater than 0.5%	Cu is an effective element for improving the strength and corrosion resistance. However, if the Cu content exceeds 0.5%, the surface on a steel pipe would often generate defects. Therefore, the Cu content is controlled at not greater than 0.5%.
Nb	Not greater than 0.01%	Nb, similar to Ti, is an effective element for refining the crystal grains and improving toughness. However, in the in-line heat treatment process, the uneven distribution of precipitation of Nb would cause the strength unevenness of the product. Therefore, the Nb content is controlled at not greater than 0.01%.

[0008] In the present invention, the billet heating temperature is not specifically defined provided that it enables the hot piercing by a piercer. The optimal temperature is determined in accordance with the variety of steels, high temperature ductility and high temperature strength. Generally, the billet is heated at a range of 1100 to 1300° C. The piercing step is a process using a piercer to make a raw hollow pipe by piercing a solid billet. In order to ensure the finish rolling comprising of stretching and sizing to be carried out easily, cross piercer by a coniform roller is employed in this step.

[0009] In the present invention, when subjecting the raw hollow pipe to the finish rolling (which is composed of stretching and sizing), the section-decrease rate is controlled to 40% or greater, and the temperature at 900° C. or higher. If the section-decrease rate is less than 40%, the recrystallization cannot be performed to realize refinement effect of crystal grains. Meanwhile, the crystal grains would sometimes grow abnormally. The upper limit of the section-decrease rate in the finish rolling is hard to define since it varies depending on the materials for pipe-making and the capability of rollers. However, since an excessive section-decrease rate would readily cause defects, its upper limit is preferably controlled at 80%.

[0010] The machining temperature in finish rolling varies according to the materials for steel pipe and the rollers. However, if the temperature is lower than 900° C., the deformation impedance of steel becomes larger, thus making the refining processing (finish rolling) with the section-decrease rate at 40% or greater difficult. Therefore, the temperature is defined to not lower than 900° C. Although the upper limit of the finish temperature is hard to be defined since it depends on the materials for steel pipe and rollers, it is still preferably defined to 1100° C.

[0011] A character of the present invention is that, the steel pipe is not cooled between the finish rolling and heat treatment of quenching and tempering but directly subjected to recrystallization treatment (normalizing). Thereby, recrystallization is induced by the combination of the machining and heat treatment and thus realizing the grain-sizing of the grains.

[0012] In the prior art, reheating process is necessary between stretch-processing and sizing-processing in rolling. But, according to the present invention, the machining process is not necessary after soaking, so that the soaking temperature can be set at the lowest temperature enabling the recrystallization, and thereby obtaining the sized recrystal grains. Since the present invention uses Cr—Mo steel, if the soaking temperature is less than 900° C., the time needed for recrystallization would be long, and the pipe-making efficiency would be remarkably degraded. On the other hand, if the soaking temperature exceeds 1000° C., the excessive refinement of crystal grains and decline of the toughness become the cause of cracking in second machining. Therefore, the soaking temperature is defined within a range of 900 to 1000° C. After soaking, direct quenching is carried out.

[0013] In the prior art that carries out offline quenching, the temperature of steel pipe is increased from room temperature, so that the steel pipe should stays in a heating furnace for a long time. Therefore, it is not economic. Furthermore, the scale would grow greatly on the surface of the product, thus requiring a removing step by acid wash or shot blast according to the uses.

[0014] According to the manufacturing method of the present invention, since the refining process of steel pipe is carried out at temperature of 900° C. or higher, the steel pipe can be soaked directly in a reheating furnace. Therefore, the remaining time in the furnace can be controlled at not greater than 30 minutes, thereby it is economic in energy expense.

[0015] In order to ensure the objective strength, the tempering in the present invention is carried out at a predetermined temperature. Since V is added to the chemical composition of Cr—Mo steel, VC would precipitate at temperature of 500 to 600° C., and thus causing the decline of the toughness. Therefore, the tempering process is carried out generally at temperature of 620 to 720° C.

EXAMPLES

[0016] Steels marked as A to M having chemical compositions shown in Table 1 were, with conventional methods, melted, cut into blocks and rolled to obtain billets each with a diameter of 225 mm. Each billet was heated at 1250° C. and then pierced by a piercer to form raw hollow pipes.

[0017] The raw hollow pipe made from the steels marked as A to G with the chemical components according to the present invention were subjected to finish rolling composed of stretching and sizing under conditions shown in Table 2 to obtain seamless steel pipes each with an outer diameter of 240 mm and a wall thickness of 8 to 30 mm. Then, without being cooled, the seamless steel pipes thus obtained were soaked directly under condition shown in Table 2, then subjected to heat treatment by quenching and tempering, thus obtaining examples 1 to 7 shown in Table 2.

[0018] Further, the raw hollow pipes made from the steels marked with H to M, having the chemical composition contents beyond the ranges prescribed in the present invention, were subjected to finish rolling composed of stretching and sizing under conditions shown in Table 2 to obtain seamless steel pipes each with an outer diameter of 240 mm and a wall thickness of 8 to 30 mm. Then, without being cooled, the seamless steel pipes thus obtained were soaked directly, and then subjected to heat treatment by quenching and tempering under the conditions shown in Table 2 within the range prescribed in the present invention, thus obtaining comparative examples 1 to 6 shown in Table 2.

[0019] Furthermore, the raw hollow pipes made from steels marked with A,C,D and F were subjected to finish rolling composed of stretching and sizing under conditions shown in Table 2 to obtain seamless steel pipes each with an outer diameter of 240 mm and a wall thickness of 8 to 30 mm. Then, without being cooled, the seamless steel pipes thus obtained were soaked directly, and then subjected to heat treatment by quenching and tempering under the conditions shown in Table 2 beyond the range prescribed in the present invention, thus obtaining comparative examples 7 to 10 shown in Table 2.

[0020] Furthermore, the hollow raw pipes made for the steels marked as B, E and G were subjected to finish rolling by stretching and sizing to produce seamless steel pipes each with an outer diameter of 240 mm and a wall thickness of 8 to 30 mm under conditions shown in Table 2. Each of the seamless steel pipes thus obtained was once cooled to room temperature in accordance with the prior art, then heated in a quenching furnace under the condition shown in Table 2, and then subjected to heat treatment of water quenching and tempering, thus obtaining the prior art examples 1 to 3 shown in Table 2.

[0021] In the column of soaking temperature in Table 2, the temperature in brackets( ) represents the soaking temperature of the steel pipe increased in quenching furnace after its being finish rolled and cooled to room temperature.

[0022] Evaluation on each seamless steel pipe is described as follows. Mechanical performances were measured using 12 C test piece prescribed in JISZ 2201 metal material tensile test piece, and the tensile test was carried out using the metal material tensile test according to JISZ 2241. TS≧590 MPa and YS≧490 MPa were target values. Furthermore, toughness was measured using V-type notch test piece with a width of 10 mm prescribed in JISZ 2202 metal material impact test piece, and the Charpy Impact test was carried out using metal material impact test prescribed in JISZ 2242. toughness≧100 was the target value. Test results are shown in Table 2.

[0023] It can be known from Table 2 that seamless steel pipes of comparative examples 1 to 10 cannot achieve the target values of strength and/or toughness.

[0024] Furthermore, although the seamless steel pipes of the prior art examples reach the target values of strength and toughness, due to the offline quenching process employed therein, the steel pipe is once cooled to the room temperature and then increased from room temperature to a higher temperature, so that the steel pipe should stays in a heating furnace for a long time. Therefore, it is not economic. Furthermore, the scale would grow greatly on the surface of the product, thus requiring a removing step by acid wash or shot blast according to the uses of the steel pipes. Therefore, comparing to the present invention, the prior art has the problem of longer production period and higher production cost.

[0025] According to the manufacturing method of seamless steel pipe for mechanical structural parts of the present invention, the billet is heated, pierced and rolled, then finish rolled by stretching and sizing at temperature of 900° C. or higher with section-decrease rate of 40% or higher. This process realizes great machining deformation. Furthermore, after finish rolled, the steel pipe is soaked directly at temperature of 900 to 1000° C. without cooled, then quenched inline, and then kept at a predetermined temperature and then subjected to tempering so as to reach a desirable strength. Due to this process, the product manufactured by inline quenching is ensured to have performances equivalent to those of the product manufactured by offline quenching in the prior art. Therefore, compared to the manufacturing method of prior art, the manufacturing method according to the present invention can achieve the effects of simplifying manufacturing process, improving pipe-making efficiency and saving energy, and producing seamless steel pipe for mechanical structural parts with excellent toughness at lower cost.

TABLE 1

		C	Si	Mn	P	S	Cr	Mo	Ti	V	N	Ti/N	Ni	Cu	Nb	Remarks
Steels	A	0.14	0.27	1.45	0.014	0.004	0.23	0.01	0.015	0.05	0.0054	2.78				
used	B	0.11	0.24	1.43	0.015	0.004	0.22	0.01	0.018	0.05	0.0052	3.46				60Q
in the	C	0.14	0.27	1.33	0.015	0.004	0.20	0.01	0.012	0.05	0.0106	1.13	0.02			
Present	D	0.19	0.24	0.94	0.010	0.007	0.53	0.21	0.018	0.06	0.0055	3.27			0.001	
Invention	E	0.18	0.21	0.94	0.009	0.007	0.52	0.19	0.013	0.05	0.0050	2.60		0.02		80QA
	F	0.14	0.23	0.78	0.020	0.003	0.48	0.33	0.016	0.03	0.0046	3.48	0.76	0.16		80QC
	G	0.13	0.25	0.80	0.017	0.003	0.46	0.31	0.019	0.04	0.0055	3.45	0.69	0.16	0.002	
Steels	H	0.14	0.31	1.46	0.010	0.004	0.22	0.01	0.020	0.06	0.0035	5.71				60Q
used	I	0.14	0.19	0.85	0.012	0.003	0.50	0.35	0.026	0.04	0.0033	7.88	0.71	0.17	0.002	80QA
in	J	0.20	0.25	0.96	0.012	0.006	0.54	0.21	0.027	0.05	0.0041	6.59			0.001	80QC
Comparative	K	0.06	0.25	0.80	0.015	0.004	0.23	0.01	0.025	0.05	0.0054	4.63				
Invention	L	0.30	0.25	1.33	0.015	0.004	0.23	0.01	0.025	0.05	0.0050	5.00				
	M	0.18	0.21	0.94	0.009	0.007	0.52	0.01	0.040	0.05	0.0050	8.00				

[0026]

TABLE 2

		Steel Sort		Section decrease In finish rolling	Finish Rolling Temp.	Soaking Temp.	Tempering Temp.	TS	YS	vE0° C.(J)			Value
Examples of the present invention	1	Steels used in present invention	A	52	1000	950	650	776	699	224	185	201	○
	2		B	52	1040	950	650	685	585	217	180	186	○
	3		C	52	1045	950	660	684	582	193	193	191	○
	4		D	52	1000	950	650	916	844	153	140	149	○
	5		E	52	910	950	650	904	828	168	163	179	○
	6		F	52	1000	950	650	881	751	187	187	185	○
	7		G	52	950	950	650	887	831	195	170	183	○
Comparative Examples	1	Steels used in present invention	H	52	1020	950	650	786	719	89	91	70	x
	2		I	52	970	950	650	925	861	61	73	50	x
	3		J	52	1050	950	650	938	857	64	57	66	x
	4		K	52	1030	950	650	570	463	243	230	221	x

1. A manufacturing method of seamless steel pipe, in which steel having the chemical composition: by weight percent, 0.10 to 0.25% of C, not greater than 1.00% of Si, 0.20 to 2.00% of Mn, not greater than 0.03% of P, not greater than 0.020% of S, 0.10 to 1.5% of Cr, not greater than 0.5% of Mo, 0.005 to 0.030% of Ti, 0.01 to 0.10% of V, and the balance being Fe and incidental impurities, and Ti/N being 3.5 or lower, is subjected to finish rolling at temperature of 900° C. or higher and a section-decrease rate of 40% or greater; then subjected to soaking directly at temperature of 900 to 1000° C. without cooling, and then quenching and tempering.

2. A manufacturing method of seamless steel pipe according to claim 1, wherein said steel further comprises one or more components selected from C: not greater than 0.5%, Ni: not greater than 1.0% and Nb: not greater than 0.01%.

* * * * *