(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 516 935 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 158(3) EPC

(43) Date of publication:
23.03.2005 Bulletin 2005/12

(21) Application number: **03733377.0**

(22) Date of filing: **11.06.2003**

(51) Int Cl.[7]: **C21D 9/08**, C22C 38/00, C22C 38/38, C22C 38/58

(86) International application number:
PCT/JP2003/007435

(87) International publication number:
WO 2004/003241 (08.01.2004 Gazette 2004/02)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

(30) Priority: **26.06.2002 JP 2002186550**
12.08.2002 JP 2002234367

(71) Applicant: **JFE Steel Corporation**
Tokyo, 100-0011 (JP)

(72) Inventors:
- **Miyata, Yukio, c/o IPD, JFE Steel Corporation**
Chiyoda-ku, Tokyo 100-0011 (JP)
- **Takojima, Kozo, c/o IPD, JFE Steel Corporation**
Chiyoda-ku, Tokyo 100-0011 (JP)
- **Kawate, Takao, c/o IPD, JFE Steel Corporation**
Chiyoda-ku, Tokyo 100-0011 (JP)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) METHOD FOR PRODUCING SEAMLESS STEEL PIPE FOR INFLATOR OF AIR BAG

(57) The invention proposes a method for manufacturing a seamless steel pipe having high strength, high toughness, and high formability for an airbag. A method for manufacturing a seamless steel pipe comprising a process for manufacturing a raw material for steel pipe having a composition containing 0.01 to 0.10% of C, 0.5% or less of Si, 0.10 to 2.00% of Mn, more than 1.0% and 2.0% or less of Cr, and 0.5% or less of Mo to form the seamless steel pipe, a process for drawing the seamless steel pipe in cold working, and a quenching and tempering process for heating the seamless steel pipe to A_{c3} transformation point or more and 1050°C or less and then quenching, then tempering at 450°C or more and A_{c1} transformation point or less is proposed. A method for manufacturing a seamless steel pipe where the cold drawing process is replaced after the quenching and tempering process is proposed. The composition may further contain, in addition to the composition, one or two or more selected from 1.0% or less of Cu, 1.0% or less of Ni, 0.10% or less of Nb, 0.10% or less of V, 0.10% or less of Ti, and 0.005% or less of B.

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Description

Technical Field

[0001] This invention relates to a high-strength seamless steel pipe, particularly relates to a high-strength seamless steel pipe having excellent toughness and formability suitable for an airbag inflator.

Background Art

[0002] Recently, improvement of safety against automobile collision has been desired earnestly, particularly, a safety device for protecting a crew at collision is actively introduced. In particular, the airbag, which is designed to expand between the crew and a steering wheel or an instrument panel, and absorb kinetic energy of the crew, thereby reduce the damage on the crew, is now being generalized. Particularly, an airbag for a driver seat installed within the steering wheel, or an airbag for a passenger seat installed within the instrument panel is being included as standard equipment. Furthermore, recently, in addition to them, to protect the crew at lateral collision, an automobile having a side airbag in the seat or a curtain type airbag for covering a side window has been increased.

[0003] Traditionally, a type using gunpowder for generating gas has been mainly used as the airbag. However, recently, from a viewpoint of recycling efficiency or environmental consciousness, a type in which inert gas such as argon is charged into an inflator under high pressure has become mainly used instead of using the gunpowder. In this type, since the inert gas must be kept to be always under high pressure, the inflator must have sufficiently high strength.

[0004] Generally, the airbag inflator is produced by aprocessing steel pipe. In the inert gas charged type airbag, since the inert gas is charged in the inflator under high pressure, from a viewpoint of reliability of the seam, a seamless steel pipe is mostly used as the pipe for the inflator. Typically, the seamless steel pipe is subjected to cold drawing process to have a predetermined size and cut into a predetermined length, then both pipe ends are processed by pressing and sealing plates are welded to the pipe ends, thereby products (inflator) are formed.

[0005] From the situation, as the steel pipe for the inflator, a seamless steel pipe having sufficient strength and toughness, excellent formability, and excellent weldability is desired. For such demand, for example, JP-A-10-140283 proposes a method for manufacturing a high-strength, high-toughness steel pipe for the airbag inflator, in which the steel containing 0.01 to 0.20% of C, 0.50% or less of Si, 0.30 to 2.00% of Mn, 0.020% or less of P, 0.020% or less of S, and 0.10% or less of Al, or further containing at least one of 0.50% or less of Mo, 0.10% or less of V, 0.50% or less of Ni, 1.00% or less of Cr, 0.50% or less of Cu, 0.10% or less of Ti, 0.10% or less of Nb, and 0.005% or less of B, and Fe and unavoidable impurities as residue is used to manufacture a seamless steel pipe. The seamless steel pipe is remained as cold working, or subjected to normalizing, normalizing, or quenching and tempering after the cold working.

[0006] JP-A-10-140249 proposes a method for producing a high-strength, high-toughness steel pipe for the airbag inflator, wherein the steel having a same composition as the composition described in JP-A-10-140283 is used to manufacture a steel pipe. The steel pipe is normalized at 850 to 1000°C, and then subjected to the cold working to have a predetermined size, or subjected to the normalization, or the quenching and tempering after a stress relief normalizing. JP-A-10-140250 proposes a method for manufacturing a high-strength, high-toughness steel pipe for the airbag inflator, wherein the steel having a same composition as the composition described in JP-A-10-140283 is used to manufacture a steel pipe. The steel pipe is quenched at 850 to 1000°C, or further tempered at 450°C or more and less than A_{c1} transformation point, then subjected to the cold working to have a predetermined size and remained as it is, or subjected to the normalizing after the cold working.

[0007] It is described that a high-strength, high-toughness steel pipe for the airbag having high dimension accuracy, excellent formability, and weldability, and a tensile strength of 590 N/mm^2 or more can be manufactured according to the technique described in JP-A-10-140283, JP-A-10-140249, or JP-A-10-140250.

Disclosure of the Invention

[0008] Recently, there has been a demand for miniaturization and weight saving of airbag system, and there is a demand for further increase of strength as the seamless steel pipe for the airbag inflator. Particularly, for the curtain type airbag, a large volume of gas is required such that the airbag can cover front and rear side-windows, in addition, a charging pressure of 50 MPa or more is required. To meet such requirements, a seamless steel pipe having 900 MPa or more of tensile strength is desired as the inflator. The seamless steel pipe should have 900 MPa or more of tensile strength finally after being subjected to the cold drawing or heat treatment.

[0009] In the technique described in JP-A-10-140283, JP-A-10-140249, or JP-A-10-140250, which aims to manufacture a 590 MPa class, high-strength, seamless steel pipe, there is a problem that the technique cannot meet the demand for further increase of strength desired for the steel pipe for the inflator.

[0010] The invention aims to solve the problem in the traditional art advantageously, and propose a method for

manufacturing a seamless steel pipe with high strength, high toughness, and high formability, the pipe having excellent formability and weldability in manufacturing of the inflator, in addition, a high tensile strength of 900 MPa or more, and high toughness or ductility exhibited in a drop weight test at -60°C for a halved steel pipe.

[0011] The inventors have earnestly made a study on various factors effected on the strength, toughness, and formability to overcome the problem. Consequently, as methods for manufacturing the seamless steel pipe, two methods below were found. (1) A seamless steel pipe having a steel composition containing a reduced content of C and proper amounts of Cr and Mo is manufactured. The seamless steel pipe is subjected to the cold drawing. Then the pipe is subjected to the quenching and tempering, or the normalizing. (2) A seamless steel pipe having a steel composition containing the reduced amount of C content and the proper amounts of Cr and Mo is manufactured. The seamless steel pipe is subjected to the quenching and tempering, or the normalizing. Then the pipe is subjected to the cold drawing. It was found that by either of the methods (1), (2), increase of the strength can be designed, particularly, a seamless steel pipe with small decrease in circumferential strength and small anisotropy is obtained.

[0012] The invention was based on the findings and completed through further investigations.

[0013] That is, the invention is summarized as follows.

(1) A method for manufacturing a seamless steel pipe with the high strength, high toughness, and high formability for the airbag characterized by comprising a process for manufacturing a raw material for steel pipe having a composition containing 0.01 to 0.10% of C, 0.5% or less of Si, 0.10 to 2.00% of Mn, more than 1.0% and 2.0% or less of Cr, and 0.5% or less of Mo by mass to form the seamless steel pipe, a quenching and tempering process for heating the seamless steel pipe at a temperature in a range of A_{c3} transformation point or more and 1050°C or less and then quenching, then tempering at a temperature in a range of 450°C or more and the A_{c1} transformation point or less, and a process for drawing the seamless steel pipe in cold working.

(2) The method for manufacturing the seamless steel pipe with the high strength, high toughness, and high formability for the airbag in (1), wherein order of the cold drawing process and the quenching and tempering process is reversed.

(3) The method for manufacturing the seamless steel pipe with the high strength, high toughness, and high formability for the airbag in (1) or (2) characterized in that the composition further contains, in addition to the above composition, one or two or more selected from 1.0% or less of Cu, 1.0% or less of Ni, 0.10% or less of Nb, 0.10% or less of V, 0.10% or less of Ti, and 0.005% or less of B by mass.

(4) The method for manufacturing the seamless steel pipe with the high strength, high toughness, and high formability for the airbag in (1), (2), or (3) characterized in that the seamless steel pipe is subj ected to the normalizing for heating the pipe to a temperature in a range from 850 to 1000°C and then air-cooling, instead of the quenching and tempering process.

Best Mode for Carrying Out the Invention

[0014] First, the reasons for setting the limit for the components of the raw material for steel pipe for use is described. Hereinafter, "% by mass" in the composition is simply shown as "%".

C: 0.01 to 0.10%

[0015] C is an element that contributes to increase of the strength of steel. However, excessive C content of more than 0.10% causes decrease in formability and weldability. On the other hand, when the C content is less than 0.01%, a desired tensile strength is hard to be ensured. Therefore, in the invention, C is limited within a range from 0.01 to 0.10%. Preferably, the C content is 0.03 to 0.08%.

Si: 0.5% or less

[0016] Si is an element that increases the strength of steel, and preferably contained at 0.1% ormore to obtain such an effect. However, since excessively large content of Si causes decrease in ductility and formability, the Si content was limited to 0.5% or less in the invention. Preferably, the Si content is 0.1 to 0.4%.

Mn: 0.10 to 2.00%

[0017] Mn is an element that improves the strength, and must be contained at 0.10% or more to ensure a desired strength in the invention. On the other hand, when 2.00% of Mn is contained, the ductility is decreased, in addition, the formability and weldability are decreased. Therefore, Mn was limited to 2.00% or less. Preferably, the Mn content is 1.00 to 1.70%.

Cr: more than 1.0% and 2.0% or less

[0018] Cr is an effective element for improving the strength and corrosion resistance of steel, and must be contained at more than 1.0% mainly for ensuring a high strength in the invention. On the other hand, when more than 2.0% of Cr is contained, the ductility is decreased, in addition, the formability, weldability, and toughness are decreased. Therefore, Cr was limited within a range of more than 1.0% and 2.0% or less. Preferably, the Cr content is 1.1 to 1.5%.

Mo: 0.5% or less

[0019] Mo is an element that increases the strength of steel and improves the quenching characteristics, and preferably contained at 0.1% or more in the invention. On the other hand, when more than 0.5% of Mo is contained, the ductility is decreased, and weld crack resistance is lowered. Therefore, Mo was limited to 0.5% or less. Preferably, the Mo content is 0.3% or less.

[0020] In the invention, in addition to the basic composition, one or two or more selected from 1.0% or less of Cu, 1.0% or less of Ni, 0.10% or less of Nb, 0.10% or less of V, 0.10% or less of Ti, and 0.005% or less of B can be further contained.

[0021] Each of Cu, Ni, Nb, V, Ti, and B acts to increase the strength, and one or two or more of them can be selectively contained as needed.

[0022] Cu is an element that increases the strength of steel, in addition, improves corrosion resistance. However, whenmore than 1.0% of Cu is contained, hot working characteristics are lowered. Therefore, Cu is preferably limited to 1.0% or less. More preferably, the Cu content is 0.5% or less.

[0023] Ni is an element that increases the strength of steel, and improves the quenching characteristics and the toughness. However, since Ni is expensive, it is preferable that Ni is limited to 1.0% or less in the invention. More preferably, the Ni content is 0.5% or less.

[0024] Nb is an element that increases the strength of steel through precipitation hardening, and improves the toughness by refining microstructure. However, when more than 0.10% of Ni is contained, the toughness is conversely decreased. Therefore, Nb is preferably limited to 0.10% or less. More preferably, the Nb content is 0.01 to 0.05%.

[0025] V is an element that increases the strength of steel through precipitation hardening, and improves the quenching characteristics. However, when more than 0.10% of V is contained, the toughness is decreased. Therefore, V is preferably limited to 0.10% or less. More preferably, the V content is 0.01 to 0.05%.

[0026] Ti is an element that increases the strength of steel through precipitation hardening, and improves the toughness by refining the microstructure. However, when more than 0.10% of Ti is contained, the toughness is conversely decreased. Therefore, Ti is preferably limited to 0.10% or less. More preferably, the Ti content is 0.005 to 0.03%.

[0027] B is an element that contributes to increase of the strength through improvement of the quenching characteristics. However, when more than 0.005% of B is contained, the toughness is decreased. Therefore, B is preferably limited to 0.005% or less. More preferably, the B content is 0.0005 to 0.002%.

[0028] The residue other than the above components is Fe and the avoidable impurities. As the avoidable impurities, 0.03% or less of P, 0.01% or less of S, and 0.10% or less of Al are allowed.

[0029] It is preferable that molten steel having the above composition is produced using a known steel making process such as a converter or an electric furnace, and then preferably made into a raw material for steel pipe such as billet using a known casting process such as a continuous casting process or an ingot making process. The slab, which is produced using the continuous casting process, can be made into the billet by rolling.

[0030] Then, the resultant raw material for steel pipe is manufactured using a typical manufacturing process of Mannesmann-plug mill method or Mannesmann-mandrel mill method, thereby a seamless steel pipe is formed. The manufacturing process of the seamless steel pipe may include other method than the above methods. The manufactured seamless steel pipe is subjected to either one of the following two treatments. (1) After the quenching and tempering, or the normalizing, the cold drawing is performed. (2) After the cold drawing, the quenching and tempering, or the normalizing is performed.

[0031] The cold drawing can be performed using a generally known cold drawing apparatus without requiring a particular apparatus. Although conditions of the cold drawing is not needed to be particularly limited as long as a predetermined size of pipe can be formed, it is preferable from a view of ensuring dimension accuracy to adjust the diameter reduction percentage to be within a range from 5 to 25% and the thickness reduction percentage to be within a range from 10 to 30%.

[0032] Heating temperature for quenching is set to be a temperature in a range from A_{c3} transformation point to 1050°C. When the heating temperature is less than A_{c3} transformation point, uniform austenization cannot be achieved. On the other hand, when the heating temperature is high, over 1050°C, crystal grains become coarse and thus the toughness is decreased. Therefore, the heating temperature for the quenching was set to be 1050°C or less in the invention. After heating at a temperature within the above range, cooling is performed by water cooling (quenching) to form a quenching microstructure (martensite microstructure). Preferably, the heating temperature for quenching is the A_{c3} transformation point or more and 950°C or less.

[0033] The tempering is performed at a temperature within a range of 450°C or more and A_{c1} transformation point or less. The tempering temperature is preferably selected to be a temperature at which the strength, toughness, and formability are best together. When the tempering temperature is less than 450°C, the tempering is inadequate, and thus a desired toughness cannot be obtained. On the other hand, when the temperature exceeds the A_{c1} transformation point, the quenching microstructure cannot be obtained, and the strength is decreased, thereby a desired strength cannot be ensured. Therefore, the tempering temperature was limited to a temperature in a range of 450°C or more and the A_{c1} transformation point or less. Preferably, the temperature is 500 to 700°C. Cooling after the tempering is

preferably performed at a rate of air cooling rate or more.

[0034] In the normalizing, heating is performed at a temperature within a range from 850 to 1000°C and then air-cooling is performed. When the normalizing temperature is less than 850°C, austenite grains cannot be unified adequately. On the other hand, when the normalizing temperature exceeds 1000°C, the crystal grains become coarse and thus a desired toughness is hardly ensured. Therefore, the normalizing temperature is preferably limited to 850 to 1000°C. Preferably, the normalizing temperature is 850 to 950°C.

[0035] The seamless steel pipe subjected to the quenching and tempering or the normalizing is then preferably subjected to descaling by acid pickling, or bend straightening as needed, thereby pipe products (steel pipe) are formed.

[0036] The seamless steel pipe manufactured by the above method has a high strength of 900 MPa in tensile strength and a high toughness or ductility exhibited in the drop weight test at -60°C for the halved steel pipe, and is formed into a steel pipe having excellent formability and weldability, thereby a steel pipe suitable for the inflator for the curtain type airbag is formed.

Example

[0037] A raw material for steel pipe (billet with a diameter of 140 mm) having a composition shown in Table 1 was heated to 1250°C, and formed into a seamless steel pipe (outer diameter of 34.0 mm and thickness of 3.2 mm, or outer diameter of 38.1 mm and thickness of 3.3 mm) by the Mannesmann-mandrel mill method. They are piercing, mandrel mill rolling, and reducer rolling.

[0038] The seamless steel pipes were subjected to the quenching and tempering or the normalizing under conditions shown in Table 2. Then, each of the seamless steel pipes after the heat treatments was subjected to the cold drawing in a diameter reduction percentage of 11.8% or 8.9%, and a thickness reduction percentage of 21.9% or 18.2% under the conditions shown in Table 2, thereby a pipe product with the diameter of 30.0 mm and the thickness of 2.5 mm or the diameter of 34.7 mm and the thickness of 2.7 mm was formed.

[0039] The seamless steel pipes were subj ected to the cold drawing in diameter reduction percentage of 11.8% or 8.9%, and thickness reduction percentage of 21.9% or 18.2% under conditions shown in Table 3, thereby a steel pipe with the diameter of 30.0 mm and the thickness of 2.5 mm or the diameter of 34.7 mm and the thickness of 2.7 mm was formed. Then, the steel pipes were subjected to the quenching and tempering or the normalizing under the conditions shown in Table 2. Then, the seamless steel pipes after the heat treatments were straightened to remove the bend, thereby the pipe products were formed.

[0040] Test pieces were sampled from the resulting pipe products, and a tensile test was carried out, thereby longitudinal tensile characteristics were examined. The tensile test was carried out in accordance with JIS Z 2241 standard after sampling No. 11 test pieces (tubular test piece) defined by JIS Z 2201. Furthermore, a hydraulic burst test was achieved, and circumferential strength was converted from the burst pressure.

[0041] For the resultant pipe products, the drop weight test was carried out at -60°C, and the toughness was examined. The drop weight test at -60°C was performed in such a way that the pipe products were semicircularly halved, then a test of dropping a weight of 100kgf from a height of 500 mm onto the pipes was carried out at -60°C. After the test, fractures were observed and occurrence of brittle failure was examined. The test was set to be repeated three times, and it was determined that a case that no brittle failure occurred in the three tests was O, a case that the brittle failure occurred in all tests was X, and other cases were Δ.

[0042] For the resultant pipe products, the pipe ends were contracted to have outer diameters of 20 mm and 25 mm using spinning machining, then cracks in the machined portion were observed, and thus the formability was evaluated. It was determined that in a case that no crack was observed, the formability was O, in a case that a crack was observed, the formability was X.

[0043] After contracting the pipe end to have the outer diameter of 20 mm using the spinning machining, the pipe end was welded with sealing plates, and after the welding, occurrence of cracks was examined visually and with a microscope, and thus the weldability was evaluated.

[0044] The obtained results are shown in Table 2 and Table 3. Each of'the examples of the invention is a seamless steel pipe having a tensile strength of 900 MPa or more and high toughness, and having an excellent formability, in addition, an excellent weldability. On the other hand, in a comparative example outside the scope of the invention, the tensile strength is less than 900 MPa, the toughness is decreased, or the formability is decreased. In the comparative example, sufficient properties as the steel pipe for the inflator for the curtain type airbag are not obtained.

Industrial Applicability

[0045] As above, according to the invention, a seamless steel pipe having high dimension accuracy, in addition, high strength, high toughness, and high formability can be stablymanufactured, thereby industrially remarkable advantages are provided.

Table 1

steel No.	chemical composition (% by mass)														remarks
	C	Si	Mn	P	S	Cr	Mo	Al	Cu	Ni	V	Nb	Ti	B	
A	0.05	0.25	1.45	0.018	0.003	1.40	0.22	0.018							Ex. of the Invention
B	0.07	0.39	1.67	0.015	0.002	1.21	0.19	0.024							Ex. of the Invention
C	0.04	0.18	1.81	0.014	0.002	1.25	0.25	0.031	0.25	0.12					Ex. of the Invention
D	0.06	0.28	1.38	0.016	0.002	1.36	0.31	0.034		0.29					Ex. of the Invention
E	0.05	0.31	1.41	0.015	0.003	1.24	0.27	0.029			0.035				Ex. of the Invention
F	0.06	0.33	1.58	0.018	0.002	1.27	0.34	0.028			0.024	0.031			Ex. of the Invention
G	0.08	0.39	1.88	0.014	0.003	1.73	0.31	0.026			0.031	0.023	0.008		Ex. of the Invention
H	0.03	0.40	1.65	0.017	0.002	1.65	0.32	0.021				0.030	0.0015		Ex. of the Invention
I	0.06	0.29	1.51	0.016	0.002	1.31	0.29	0.030					0.0013	0.0012	Ex. of the Invention
J	0.06	0.20	1.32	0.016	0.004	1.25	0.20	0.027	0.18	0.10	0.033	0.021	0.0011		Ex. of the Invention
K	0.12	0.25	0.85	0.014	0.003	1.49	0.31	0.033							Comp. Ex.
L	0.07	0.74	1.54	0.013	0.003	1.67	0.28	0.029							Comp. Ex.
M	0.06	0.33	0.02	0.014	0.002	1.56	0.27	0.028							Comp. Ex.
N	0.06	0.27	2.34	0.013	0.002	1.43	0.32	0.031							Comp. Ex.
O	0.06	0.30	1.28	0.014	0.003	0.85	0.21	0.029							Comp. Ex.
P	0.08	0.27	1.43	0.015	0.002	2.28	0.33	0.028							Comp. Ex.
Q	0.07	0.34	1.59	0.017	0.003	1.29	0.74	0.031							Comp. Ex.

Table 2

steel pipe No.	steel No.	steel pipe size before drawing		heat treatment conditions before drawing			steel pipe size after drawing		depression percentage in cold drawing		heat treatment conditions after drawing		characteristics of seamless steel pipe products						remarks
													longitudinal tension property		circumferential tension property	Tough-ness	Machin-ability	Weld-ability	
		outer diameter (mm)	thickness (mm)	quenching temperature (°C)	tempering temperature (°C)	normalizing temperature (°C)	outer diameter (mm)	thickness (mm)	diameter reduction (%)	thickness reduction (%)	quenching temperature (°C)	tempering temperature (°C)	TS (MPa)	El (%)	TS (MPa)				
1	A	34.0	3.2	920	600		30.0	2.5	11.8	21.9			1025	14.3	965	O	O	O	Ex. of the Invention
2		34.0	3.2				30.0	2.5	11.8	21.9			842	16.8	748	O	O	O	Comp. Ex.
4	B	38.1	3.3	930	580		34.7	2.7	8.9	18.2			1068	15.8	946	O	O	O	Ex. of the Invention
5	C	38.1	3.3	920	550		34.7	2.7	8.9	18.2			1063	14.9	937	O	O	O	Invention in the Application
6		38.1	3.3	920			34.7	2.7	8.9	18.2			1116	12.0	978	×	×	O	Comp. Ex.
7	D	34.0	3.2	920	580		30.0	2.5	11.8	21.9			1087	14.6	968	O	O	O	Ex. of the Invention
8	E	38.1	3.3	920	600		34.7	2.7	8.9	18.2			1132	15.2	1002	O	O	O	Ex. of the Invention
9	F	38.1	3.3	920	600		34.7	2.7	8.9	18.2			1066	14.3	954	O	O	O	Ex. of the Invention
10	G	34.0	3.2			950	30.0	2.5	11.8	21.9			1039	15.5	923	O	O	O	Ex. of the Invention
11		34.0	3.2	920	630		30.0	2.5	11.8	21.9			1023	14.9	938	O	O	O	Ex. of the Invention
12	H	34.0	3.2	920	500		30.0	2.5	11.8	21.9			1028	14.8	938	O	O	O	Ex. of the Invention
13	I	34.0	3.2	920	480		30.0	2.5	11.8	21.9			1086	15.4	965	O	O	O	Ex. of the Invention
14	J	38.1	3.3	920	460		34.7	2.7	8.9	18.2			1073	13.9	926	O	O	O	Ex. of the Invention
15	K	34.0	3.2	920	600		30.0	2.5	11.8	21.9			1099	11.8	957	×	×	×	Comp. Ex.
16	L	34.0	3.2	920	600		30.0	2.5	11.8	21.9			1058	12.0	938	×	×	×	Comp. Ex.
17	M	38.1	3.3	920	450		34.7	2.7	8.9	18.2			991	15.6	833	O	O	O	Comp. Ex.
18	N	38.1	3.3	920	650		34.7	2.7	8.9	18.2			1069	11.6	965	×	×	×	Comp. Ex.
19	O	38.1	3.3	920	460		34.7	2.7	8.9	18.2			986	14.9	823	O	O	O	Comp. Ex.
20	P	38.1	3.3	920	630		34.7	2.7	8.9	18.2			1106	11.6	972	×	×	×	Comp. Ex.
21	Q	38.1	3.3	920	600		34.7	2.7	8.9	18.2			1139	12.1	989	×	×	×	Comp. Ex.

Table 3

steel pipe No.	steel No.	steel pipe size before drawing		steel pipe size after cold drawing		depression percentage in cold drawing		heat treatment conditions after cold drawing			characteristics of seamless steel pipe products						remarks
		outer diameter (mm)	thickness (mm)	outer diameter (mm)	thickness (mm)	diameter reduction (%)	thickness reduction (%)	quenching temperature (°C)	tempering temperature (°C)	normalizing temperature (°C)	longitudinal tension property TS (MPa)	longitudinal tension property El (%)	circumferential tension property TS (MPa)	toughness	machinability	weldability	
22	A	34.0	3.2	30.0	2.5	11.8	21.9	920	500		1041	14.7	1033	O	O	O	Ex. of the Invention
23		34.0	3.2	30.0	2.5	11.8	21.9				840	16.8	748	O	O	O	Comp. Ex.
24		34.0	3.2	30.0	2.5	11.8	21.9	920	600		987	13.8	983	O	O	O	Ex. of the Invention
25	B	38.1	3.3	34.7	2.7	8.9	18.2	930	500		942	15.3	938	O	O	O	Invention in the Application
26	C	38.1	3.3	34.7	2.7	8.9	18.2	920	470		963	15.2	952	O	O	O	Comp. Ex.
27		38.1	3.3	34.7	2.7	8.9	18.2	920			1237	11.7	1210	×	×	O	Ex. of the Invention
28	D	34.0	3.2	30.0	2.5	11.8	21.9	920	500		1025	14.5	1025	O	O	O	Ex. of the Invention
29	E	38.1	3.3	34.7	2.7	8.9	18.2	920	530		1128	14.2	1132	O	O	O	Ex. of the Invention
30	F	38.1	3.3	34.7	2.7	8.9	18.2	920	520		1055	13.6	1049	O	O	O	Ex. of the Invention
31	G	34.0	3.2	30.0	2.5	11.8	21.9			950	923	14.8	918	O	O	O	Ex. of the Invention
32		34.0	3.2	30.0	2.5	11.8	21.9	920	550		1065	14.0	1066	O	O	O	Ex. of the Invention
33	H	34.0	3.2	30.0	2.5	11.8	21.9	920	460		964	14.8	965	O	O	O	Ex. of the Invention
34	I	34.0	3.2	30.0	2.5	11.8	21.9	920	450		934	14.8	965	O	O	O	Ex. of the Invention
35	J	38.1	3.3	34.7	2.7	8.9	18.2	920	450		921	15.2	918	O	O	O	Comp. Ex.
36	K	34.0	3.2	30.0	2.5	11.8	21.9	920	550		1051	12.3	1049	×	×	×	Comp. Ex.
37	L	34.0	3.2	30.0	2.5	11.8	21.9	920	550		1021	12.5	1023	×	×	×	Comp. Ex.
38	M	38.1	3.3	34.7	2.7	8.9	18.2	920	450		802	15.9	800	O	O	O	Comp. Ex.
39	N	38.1	3.3	34.7	2.7	8.9	18.2	920	600		1099	11.2	1093	×	×	×	Comp. Ex.
40	O	38.1	3.3	34.7	2.7	8.9	18.2	920	460		783	15.9	780	O	O	O	Comp. Ex.
41	P	38.1	3.3	34.7	2.7	8.9	18.2	920	600		1056	12.3	1055	×	×	×	Comp. Ex.
42	Q	38.1	3.3	34.7	2.7	8.9	18.2	920	600		988	13.5	989	×	×	×	Comp. Ex.

Claims

1. A method for manufacturing a seamless steel pipe having high strength, high toughness, and high formability for an airbag **characterized by** comprising,

   a process for manufacturing a steel pipe having a composition containing 0.01 to 0.10% of C, 0.5% or less of Si, 0.10 to 2.00% of Mn, more than 1.0% and 2.0% or less of Cr, and 0. 5% or less of Mo by mass to form the seamless steel pipe,

   a quenching and tempering process for heating the seamless steel pipe to a temperature in a range of A_{c3} transformation point or more and 1050°C or less and then quenching, then tempering at a temperature in a range of 450°C or more and A_{c1} transformation point or less, and

   a cold drawing process for drawing the seamless steel pipe in cold working.

2. The method for manufacturing the seamless steel pipe having the high strength, high toughness, and high formability for the airbag in claim 1, wherein order of the cold drawing process and the quenching and tempering process is reversed.

3. The method for manufacturing the seamless steel pipe having the high strength, high toughness, and high formability for the airbag according to claim 1 and 2 **characterized in that** the composition further contains, at least one element selected from 1.0% or less of Cu, 1.0% or less of Ni, 0.10% or less of Nb, 0.10% or less of V, 0.10% or less of Ti, and 0.005% or less of B.

4. The method for manufacturing the seamless steel pipe having the high strength, high toughness, and high formability for the airbag according to claim 1 to 3 **characterized in that** the seamless steel pipe is subjected to normalizing, for heating to a temperature in a range from 850 to 1000°C and then air cooling, instead of the quenching and tempering process.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/07435

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] C21D9/08, C22C38/00, 38/38, 38/58

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.Cl[7] C21D9/08, C22C38/00, 38/38, 38/58

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

Jitsuyo Shinan Koho	1922-1996	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)
WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 8-325641 A (Sumitomo Metal Industries, Ltd.), 10 December, 1996 (10.12.96), Full text (Family: none)	1 2-4
Y	JP 3220975 B2 (Sumitomo Metal Industries, Ltd.), 22 October, 2001 (22.10.01), Full text (Family: none)	2-4
Y	JP 3250211 B2 (Sumitomo Metal Industries, Ltd.), 28 January, 2002 (28.01.02), Full text (Family: none)	4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 August, 2003 (12.08.03)	26 August, 2003 (26.08.03)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)