US 20170335420A1

(19) **United States**

(12) **Patent Application Publication**

CHOI et al.

(10) **Pub. No.: US 2017/0335420 A1**

(43) **Pub. Date: Nov. 23, 2017**

(54) LEAN DUPLEX STAINLESS STEEL HAVING SUPERB DRAWING PROPERTY AND METHOD FOR PRODUCING SAME

(71) Applicant: **POSCO**, Pohang-si (KR)

(72) Inventors: **Jeom Yong CHOI**, Pohang-si (KR); **Sung Yeun WON**, Daegu (KR); **Jong Su PAEK**, Pohang-si (KR)

(21) Appl. No.: **15/534,227**

(22) PCT Filed: **Dec. 22, 2015**

(86) PCT No.: **PCT/KR2015/014089**

§ 371 (c)(1),
(2) Date: **Jun. 8, 2017**

(30) **Foreign Application Priority Data**

Dec. 26, 2014 (KR) 10-2014-0190492

Publication Classification

(51) **Int. Cl.**

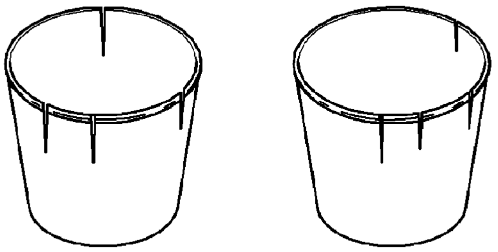
C21D 8/02	(2006.01)
C22C 38/04	(2006.01)
C21D 1/26	(2006.01)
C22C 38/00	(2006.01)
C21D 6/00	(2006.01)
C22C 38/40	(2006.01)
C22C 38/02	(2006.01)

(52) **U.S. Cl.**

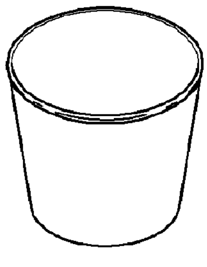
CPC ***C21D 8/0263*** (2013.01); ***C22C 38/40*** (2013.01); ***C22C 38/04*** (2013.01); ***C22C 38/02*** (2013.01); ***C22C 38/001*** (2013.01); ***C21D 8/0236*** (2013.01); ***C21D 6/004*** (2013.01); ***C21D 1/26*** (2013.01); ***C21D 8/0226*** (2013.01); ***C21D 8/0205*** (2013.01); ***C21D 6/008*** (2013.01); ***C21D 6/005*** (2013.01); *C21D 2211/001* (2013.01); *C21D 2211/005* (2013.01)

(57) ABSTRACT

Provided are lean duplex stainless steel in which delayed fracture does not occur and thus a drawing property is improved, and a method for producing the lean duplex stainless steel. The lean duplex stainless steel having a superb drawing property according to the present disclosure includes, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2%, and the remainder of Fe and other inevitable impurities, and, as annealed dual-phase steel of ferrite and austenite, Md_SIM10 corresponding to a temperature measured when an amount of strain-induced martensite formed after 0.3 true strain reaches 10%, and a limit drawing ratio (LDR) satisfy the expressions below. −30° C.Md_SIM10≤0° C. - - - (expression 1) and 2.08≤LDR≤2.18 - - - (expression 2)



CUP WITH DELAYED FRACTURE OCCURRENCES



CUP WITH NO DELAYED FRACTURE OCCURRENCES

Fig.1

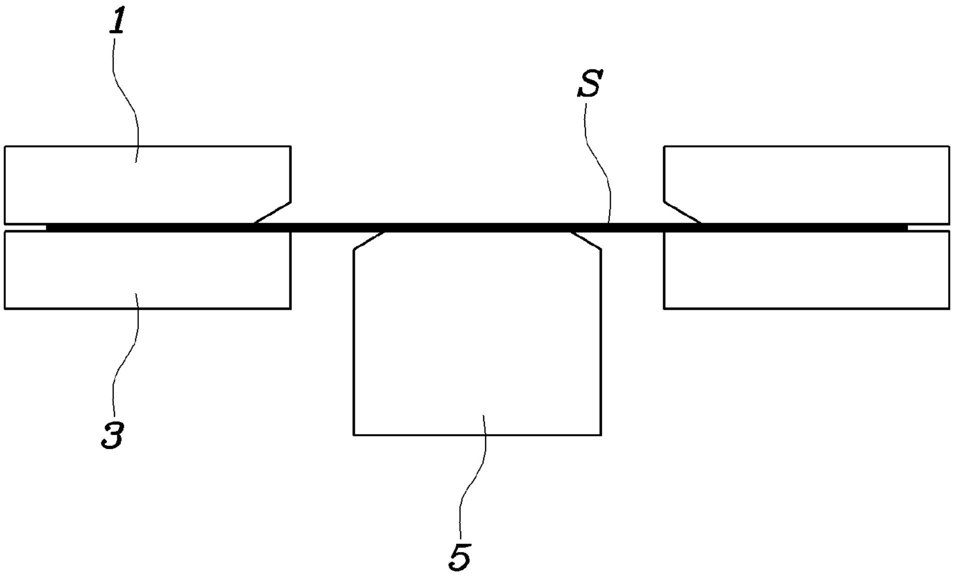


Fig. 2

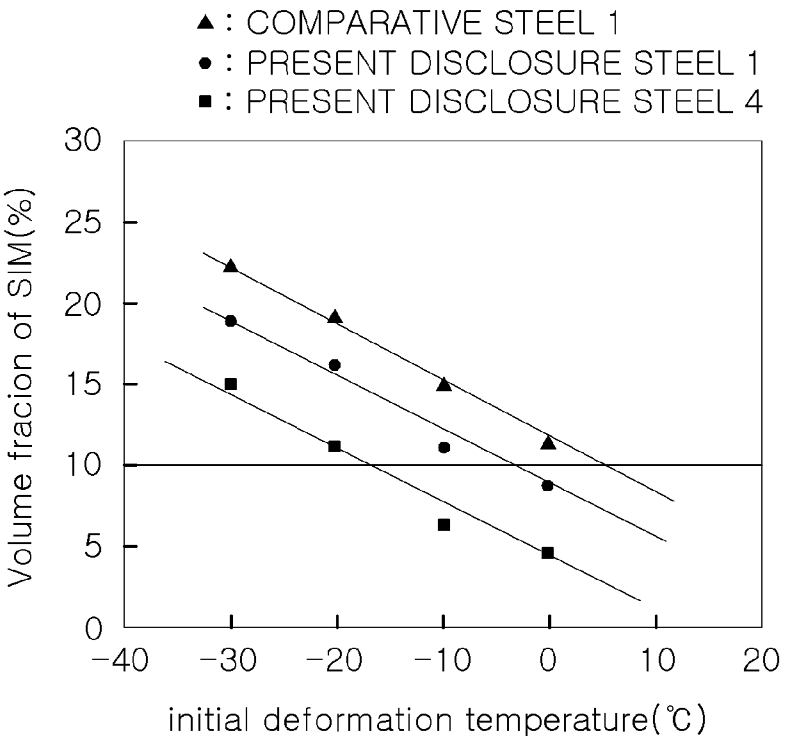

▲ : COMPARATIVE STEEL 1
● : PRESENT DISCLOSURE STEEL 1
■ : PRESENT DISCLOSURE STEEL 4
Volume fracion of SIM(%)
30
25
20
15
10
5
0
−40
−30
−20
−10
0
10
20
initial deformation temperature(℃)

Fig. 3

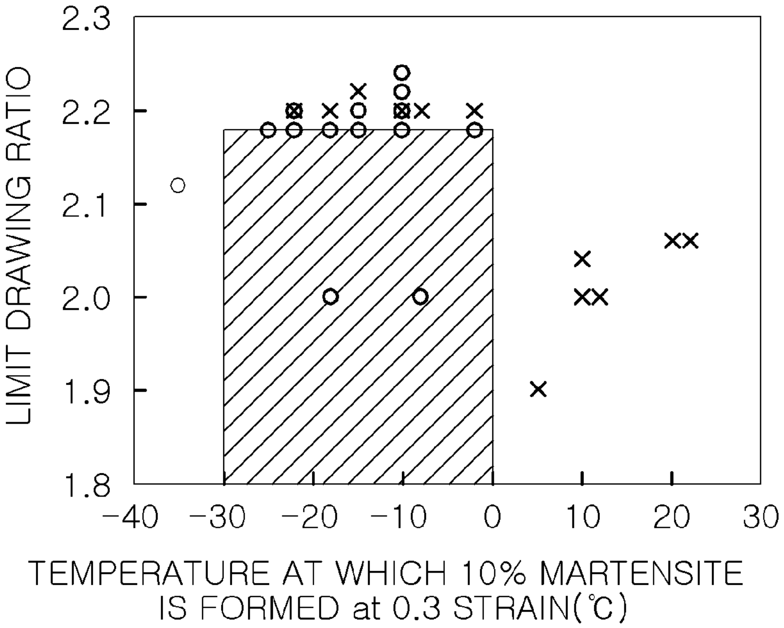
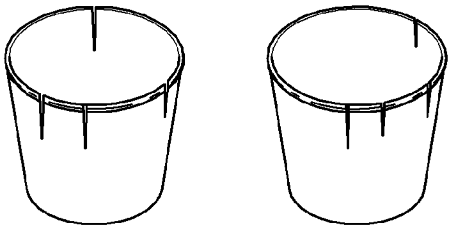
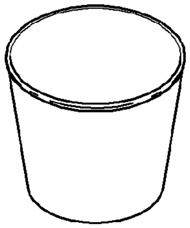

2.3
2.2
2.1
2.0
1.9
1.8
LIMIT DRAWING RATIO
−40
−30
−20
−10
0
10
20
30
TEMPERATURE AT WHICH 10% MARTENSITE IS FORMED at 0.3 STRAIN(℃)

Fig. 4



CUP WITH DELAYED FRACTURE OCCURRENCES



CUP WITH NO DELAYED FRACTURE OCCURRENCES

LEAN DUPLEX STAINLESS STEEL HAVING SUPERB DRAWING PROPERTY AND METHOD FOR PRODUCING SAME

TECHNICAL FIELD

[0001] The present disclosure relates to lean duplex stainless steel having a superb drawing property and a method for producing the same.

BACKGROUND ART

[0002] Austenitic stainless steel having favorable workability and acid resistance generally contains Cr and Ni as main raw materials with iron (Fe) as a base metal. In addition, austenitic stainless steel has been developed into various steel types suiting for various applications by adding other elements such as Mo and Cu.

[0003] Such austenitic stainless steel types are a steel type having excellent acid resistance and pitting corrosion resistance, and contains a Ni component in 8% or greater in weight % while being low carbon. This causes a problem of reducing price competitiveness due to the high range of fluctuation in costs with an increase in the Ni price.

[0004] Accordingly, development of new steel types capable of securing equal or higher acid resistance compared to austenitic stainless steel types while lowering a Ni content has been required for complementing this problem.

[0005] In view of the above, duplex stainless steel having a microstructure formed with a mixture of an austenite phase and a ferrite phase has been used, and such duplex stainless steel exhibits both austenitic and ferritic properties.

[0006] Various duplex stainless steel has been proposed so far.

[0007] Duplex stainless steel provides excellent corrosion resistance under diverse corrosive environments, and exhibits more superior corrosion resistance compared to austenitic stainless phase such as 304, 316 and the like of AISI.

[0008] Such duplex stainless steel causes an increase in the manufacturing costs due to high-priced elements such as Ni and Mo, and also causes reduction in the price competitiveness compared to other steel types by consuming Ni, Mo and the like.

[0009] Accordingly, among duplex stainless steel, interest in lean duplex stainless steel further enhancing an advantage of low alloy costs by excluding high-priced alloy elements such as Ni and Mo and adding low-priced alloy elements instead of these high-priced elements tends to grow recently.

[0010] Recently developed lean duplex stainless steel has been widely used mostly in storage containers, transport containers and the like, however, like other common duplex stainless steel, such lean duplex stainless steel has a problem of formability limit compared to austenite-based.

[0011] Accordingly, when controlling an austenite phase fraction present in the lean duplex stainless steel and a formation behavior of strain-induced martensite, workability is capable of being improved, and tendency to improve workability by controlling the amount of C+N in the austenite phase present in the ferrite-austenite phase also exists.

[0012] Commonly, this uses transformation induced plasticity occurring in semi-stable austenite steel, and when strain-induced martensite corresponding to a hard phase is formed in a deformed site during forming processing, local necking occurring during the process is suppressed, and deformation spreads to sites adjacent to where the strain-induced martensite is formed.

[0013] Accordingly, elongation is enhanced when controlling a process curing rate by controlling the amount of the strain-induced martensite formed during deformation, however, when used for a drawing, there is a problem in that process-induced martensite is formed by cup drawing processing causing delayed fractures.

[0014] Meanwhile, lean duplex stainless steel is disclosed in the publication of Japanese Patent Application Laid-Open Publication No. S61-056267, the publication of WO 02/027056 and the publication of WO 96/18751. Among these, lean duplex stainless steel disclosed in the publication of Japanese Patent Application Laid-Open Publication No. S61-056267 and the publication of WO 02/027056 is standardized as ASTM A240, and the former corresponds to S32304 (representative component 23Cr-4Ni-0.13N) and the latter corresponds to S32101 (representative component 21Cr-1.5Ni-5Mn-0.22N).

[0015] In addition, S81921 steel disclosed in the publication of Korean Patent Application Laid-Open Publication No. 2006-0074400, and standardized as ASTM A240 includes high-priced alloy elements with the content of Ni and Mo being 2.5% and 2.4%, respectively, in weight %.

[0016] Such duplex stainless steel designs steel with a priority in the acid resistance strengthening rather than formability, and provides acid resistance superior than required acid resistance in specific applications. Stress corrosion resistance is also more superior than design requirements providing technical solutions, however, formability, a factor relating to workability, is inferior than in austenitic stainless steel. This causes many restrictions in the use in various industrial fields requiring forming, bending and the like, which is not feasible in economic aspects. Accordingly, development of duplex stainless steel for industrial facilities and various forming processing securing equal or higher acid resistance compared to 304 steel, 304L steel and 316 steel and particularly securing formability at an equal level with 304 steel while reducing manufacturing costs by excluding these high-priced elements has been required.

[0017] Particularly, austenitic stainless steel having excellent formability contains 4% or higher of high-priced Ni and therefore, there are problems in that material costs are very high when manufactured, and Ni and the like that are precious resources are consumed in large quantities.

[0018] In addition, a large quantity of Mn greatly increases nitrogen solid solubility of steel for securing acid resistance of lean duplex stainless steel, but has a problem of inhibiting acid resistance by readily forming inclusions such as MnS harmful for acid resistance. Environmental problems also occur due to Mn dust particles and the like produced during electric furnace operations.

[0019] Matters described as the background art are just for enhancing understanding on the background of the present disclosure, and are not to be accepted as an admission that the present disclosure corresponds to existing technologies already known to those skilled in the art.

DISCLOSURE

Technical Problem

[0020] The present disclosure has been made in view of the above, and the present disclosure is directed to providing lean duplex stainless steel having a superb drawing property reducing costs while preventing delayed fracture occurrences during cup forming and securing excellent formability and corrosion resistance, and a method for producing the same.

Technical Solution

[0021] In view of the above, lean duplex stainless steel having a superb drawing property according to one embodiment of the present disclosure includes, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2%, and the remainder of Fe and other inevitable impurities, wherein, as annealed dual-phase steel of ferrite and austenite, Md_SIM10 corresponding to a temperature measured when an amount of strain-induced martensite formed after 0.3 true strain reaches 10%, and a limit drawing ratio (LDR) satisfy the following expressions.

$$-30^\circ \text{ C.} \le \text{Md\_SIM10} \le 0^\circ \text{ C.} \qquad \text{(Expression 1)}$$

$$2.08 \le \text{LDR} \le 2.18 \qquad \text{(Expression 2)}$$

[0022] An austenite fraction satisfies the following range, and the rest are formed with ferrite.

$$30 \le \text{-austenite fraction } (\gamma) \le 70$$

[0023] Lean duplex stainless steel having a superb drawing property according to one embodiment of the present disclosure is cold annealing steel including, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2%, and the remainder of Fe and other inevitable impurities in a range of 950° C. to 1100° C.

Advantageous Effects

[0024] According to the present disclosure, resources can be saved and costs can be reduced by controlling the content of Ni, Si, Cu and Mo alloy components that are high-priced elements.

[0025] In addition, there are advantages in that workability is improved as well as securing equal or higher acid resistance compared to 304 steel.

DESCRIPTION OF DRAWINGS

[0026] FIG. **1** is a diagram of an apparatus measuring a limit drawing ratio.

[0027] FIG. **2** is a graph showing Md_SIM10 of steel of the present disclosure and comparative steel.

[0028] FIG. **3** is a diagram showing a relation between Md_SIM10 and a limit drawing ratio.

[0029] FIG. **4** is a diagram showing the presence of delayed fractures after cup drawing.

MODE FOR DISCLOSURE

[0030] Hereinafter, embodiments and other matters needed for those skilled in the art to readily understand the contents of the present disclosure will be described in detail with reference to the accompanying drawings.

[0031] However, the present disclosure may be implemented in various different forms within the range described in the claims, and embodiments described below are only illustrative despite the expression.

[0032] The present disclosure relates to, among duplex stainless steel having a dual-phase of austenite phase and ferrite phase, lean duplex stainless steel having a superb drawing property and lowering the content of high-priced alloy elements such as Ni, Mo, Si and Cu, and a method for producing the same.

[0033] Lean duplex stainless steel is capable of maintaining equal or higher acid resistance compared to 304 steel that is general austenitic stainless steel, and is also capable of securing equal or higher elongation compared to austenitic stainless steel, and therefore, is capable securing equal or higher elongation compared to 304 steel.

[0034] The lean duplex stainless steel having a superb drawing property of the present disclosure may be used under a corrosive environment or in general products for forming, and may be prepared into products such as strips, bars, plates, sheets, pipes, or tubes to be used.

[0035] Lean duplex stainless steel is economical with a small Ni content while securing equal acid resistance with 304 steel and 316 steel that are austenitic stainless steel, and readily secures high strength, and therefore, is capable of being used as a steel material for desalination facilities and industrial facilities such as pulp, paper and chemical facilities, and in the present disclosure, dual phase-structured steel in which a ferrite phase and an austenite phase coexist is developed using a method of securing formability and acid resistance equal to austenite-based while reducing Ni, Mn and the like.

[0036] Hereinafter, the lean duplex stainless steel having a superb drawing property of the present disclosure will be described in detail.

[0037] According to the present disclosure, a drawing property as well as an equal level of acid resistance with 304 steel may be secured while having excellent overall properties of duplex stainless steel formed with austenite.ferrite. In other words, in the present disclosure, a high nitrogen content is included, and alloy elements of high-priced Ni, Si, Mo, Cu and the like are controlled to an optimal level while optimizing a Mn content as low carbon chromic stainless steel. Accordingly, by properly controlling phase fractions of austenite and ferrite utilizing constituents and annealing temperatures, and adjusting the range of Md_SIM10 temperature measured at a common tensile strain rate—that is, a temperature at which the amount of strain-induced martensite measured after imposing 0.3 true strain reaches 10%—to be from −30° C. to 0° C., duplex stainless steel of austenite and ferrite having excellent formability and acid resistance with no delayed fractures during forming processing is produced.

[0038] The lean duplex stainless steel having a superb drawing property according to the present disclosure greatly reduces raw material costs among manufacturing costs and thereby greatly enhances price competitiveness, and secures acid resistance while greatly enhancing delayed fracture resistance after forming, and therefore, is capable of replacing 304 steel used for forming.

[0039] The lean duplex stainless steel having a superb drawing property of the present disclosure includes, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2%, and the remainder of Fe and other inevitable impurities.

[0040] Hereinafter, reasons for limiting the components of the present disclosure will be described.

[0041] C is an austenite forming element, and is an element effective in increasing material strength by inducing solid solution strengthening, and needs to be added in 0.02% or greater for improving strength. However, when added in excess, C readily bonds to carbide-forming elements such as Cr effective for acid resistance at a ferrite-austenite phase boundary lowering the Cr content around the grain boundary and reducing resistance for corrosion resistance, and therefore, C needs to be added in 0.08% or less for maximizing acid resistance.

[0042] Si is partly added for a deoxidation effect, and is a ferrite-forming element thickened to ferrite when annealed. Accordingly, Si needs to be added in 0.5% or greater for securing a proper ferrite phase fraction. When added in less than the above-mentioned range, formation of strain-induced martensite of the austenite phase is activated in the alloy system, however, when forming, delayed fractures occur due to excessive strain-induced martensite formation causing formability decline.

[0043] When Si is added in greater than 1.3%, in deformation mechanism of the austenite phase present in the dual-phase steel, a transition in the deformation mechanism occurs due to the formation of mechanical twin in forming the strain-induced martensite, which is not suitable for a purpose of the present disclosure aiming to use an effect of strain-induced martensite formation. In addition, when Si is added in excess, slag flowability is reduced during steel manufacturing, and inclusions are formed by bonding with oxygen decreasing acid resistance, and therefore, the Si content is limited to 0.5% to 1.3%.

[0044] N is an element greatly contributing to austenite phase stabilization together with Ni in the duplex stainless steel, and is one of the elements thickened to the austenite phase when annealed. Accordingly, when the N content increases, acid resistance increases concomitantly, and high strengthening is obtained. However, solid solubility of N changes depending on the content of added Mn, and when the N content is greater than 0.3% in the Mn range of the present disclosure, blow holes, pin holes and the like are produced during casting due to excessive solid solubility of nitrogen inducing surface defects, and therefore, stable manufacturing of steel becomes difficult. In addition, N needs to be added in 0.2% or greater for securing acid resistance at a level of 304 steel, and when added in less than the above-mentioned range, a proper phase fraction is difficult to secure.

[0045] Accordingly, the N content is preferably limited to 0.2% to 0.3%.

[0046] Mn is a deoxidizer and an element for increasing nitrogen solid solubility, and, as an austenite-forming element, is used for replacing high-priced Ni.

[0047] When the content is greater than 3.5%, acid resistance of a 304 level is difficult to secure. This is due to the fact that adding a large quantity of Mn is effective in solid solubility of nitrogen, but reduces acid resistance by forming MnS through bonding with S in the steel. In addition, when the Mn content is less than 2.5%, a proper austenite phase fraction is difficult to secure even when controlling Ni, Cu, N and the like, austenite-forming elements, and sufficient solid solution of nitrogen may not be obtained at atmospheric pressure due to low solid solubility of added N. Accordingly, the content of Mn is limited to 2.5% to 3.5%.

[0048] Cr is a ferrite-stabilizing element together with Si, and is an essential element for securing acid resistance as well as performing a main role in securing a ferrite phase of dual-phase stainless steel.

[0049] When the content increases, acid resistance increases, however, for maintaining the phase fraction, the content of high-priced Ni or other austenite-forming elements needs to be increased. Accordingly, for securing acid resistance of STS 304 or higher while maintaining the phase fraction of dual-phase stainless steel, the Cr content is limited to 19% to 21%.

[0050] Ni is an austenite-stabilizing element together with Mn, Cu and N, and performs a main role in securing an austenite phase of the duplex stainless steel. For cost savings, the content of Mn and N that are other austenite phase-forming elements increases in place of reducing the high-priced Ni content as much as possible, and as a result, balance in the phase fraction is sufficiently maintained even with a decrease in the Ni content. However, Ni needs to be added in 0.6% or greater for securing sufficient austenite stability to suppress the formation of strain-induced martensite produced during cold working. When a large quantity of Ni is added, an austenite fraction increases and a proper austenite phase fraction is difficult to secure, and particularly, it is difficult to secure competitiveness compared to 304 since product manufacturing costs increase due to high-priced Ni. Accordingly, the Ni content is preferably limited to 0.6% to 1.2%.

[0051] Cu is an austenite-stabilizing element together with Mn, Ni and N, and performs a main role in securing an austenite phase of the duplex stainless steel. For cost savings, the content of Cu, Mn and N that are other austenite phase-forming elements increases in place of reducing the high-priced Ni content as much as possible, and as a result, balance in the phase fraction is sufficiently maintained even with a decrease in the Ni content. However, Cu needs to be added in 0.6% or greater for securing sufficient austenite stability to suppress the formation of strain-induced martensite produced during cold working. When a large quantity of Cu is added, an austenite fraction increases and a proper austenite phase fraction is difficult to secure, and particularly, a welding problem may occur during production due to a problem of Cu solid solubility. Accordingly, the Cu content is preferably limited to 0.6% to 1.2%.

[0052] When applying Md_{30} (temperature forming 50% of martensite in a material deformed after applying 0.3 true strain during a tensile test), a temperature at which strain-induced martensite is formed, in common duplex stainless steel in the present disclosure, the amount of the strain-induced martensite is observed to be 30% or less in most steel, and it is seen that the Md_{30} temperature described above is difficult to define using common definitions for Md_{30}.

[0053] Accordingly, based on the fact that strain-induced martensite is a main cause of delayed fractures occurring after cup drawing, the Md_{30} temperature is redefined as follows after giving diverse considerations on a strain-induced martensite-forming temperature and a limit drawing ratio caused by delayed fractures, and evaluations are performed.

[0054] The inventors of the present disclosure define a temperature at which an amount of the strain-induced martensite formed after applying 0.3 true strain at a common tensile strain rate reaches 10% as Md_SIM10.

[0055] After defining a temperature at which the strain-induced martensite is formed in the duplex stainless steel using such a method, correlation with delayed fractures occurring after cup drawing is analyzed.

[0056] The lean duplex stainless steel having a superb drawing property of the present disclosure has Md_SIM10 of −30° C. to 0° C.

[0057] Strain-induced martensite is a hard phase formed when unstable austenite is deformed, and induces work hardening and contributes to an increase in the elongation of steel. In the present disclosure corresponding to duplex stainless steel formed with austenite and ferrite, stability of the austenite phase may be controlled using proper distribution of alloy elements.

[0058] The inventors of the present disclosure have the strain-induced martensite being formed before and after local necking during tensile strain. However, when the strain-induced martensite is formed too rapidly, strength increases at an early stage of the strain reducing workability, and when strain-induced martensite is formed at a later stage of the strain, the material is deformed too much, and therefore, the strain-induced martensite may not contribute to workability enhancement.

[0059] As in the present disclosure, by limiting the 10% martensite-forming temperature, designing components and controlling a phase fraction, sufficient work hardening is induced during forming to improve formability, and delayed fractures occurring after the forming may be sufficiently suppressed.

[0060] The lean duplex stainless steel having a superb drawing property according to the present disclosure is preferably formed with 30% to 70% of austenite and 70% to 30% of ferrite in a volume fraction.

[0061] In order for the strain-induced martensite to be formed in an austenite phase and contribute to workability when deformed at a normal rate, 30% of more of the austenite fraction needs to be present, and particularly when the austenite fraction is 30% or less, that is, when the ferrite phase fraction is 70% or greater, surface unevenness is formed on the surface after the forming due to ferrite. In addition, when the austenite fraction is 70% or greater, austenite stability greatly changes unintendedly due to alloy element distribution during annealing (a phenomenon of austenite-forming element being thickened to an austenite phase, and a ferrite-forming element being thickened to ferrite), and delayed fractures readily occur by forming excessive strain-induced martensite during forming leading to high strengthening.

[0062] Accordingly, the austenite fraction is preferably 70% or less.

[0063] As shown in FIG. **1**, a mold configured with a die (**1**), a holder (**3**) and a punch (**5**) is used as a method of evaluating a drawing property.

[0064] A material (S) is cut into a circular shape and is placed on a holder (**3**), and while the material (S) located between the holder (**3**) and a die (**1**) is held with a certain pressure (1 ton) by moving the die (**1**), the material (S) is made into a cup shape by moving the punch (**5**).

[0065] Herein, the punch (**5**) has a diameter of approximately 50 mm, and when the material is formed into a complete cup shape depending on the material (S) size, a ratio of the first material (S) size and the punch (**5**) is referred to as a drawing ratio. As the material (S) size increases, the material (S) does not readily change into a cup shape since force held by the die (**1**) and the holder (**3**) increases.

[0066] A ratio between the maximum material (S) diameter and the punch (**5**) diameter at which no fractures occur when carrying out a drawing test as the material (S) increases by a unit of 1 mm is referred to as a limit drawing ratio (LDR).

[0067] Limit drawing ratio (LDR)=diameter of blank with no fractures/punch diameter (Φ50 mm)

[0068] A limit drawing ratio (LDR) value, a drawing index, is evaluated through an LDR evaluation method, a drawing property evaluation method. In addition, delayed fractures are determined as, after a cup prepared after the drawing property evaluation (cup with no crack occurrences when drawing) is left unattended for 24 hours at room temperature, the occurrences of cracks on the drawn cup. Commonly, delayed fractures are considered to occur when cracks occur within 24 hours after cup forming, and the drawing ratio with no crack occurrences after 24 hours is referred to as a limit drawing ratio. In other words, as the limit drawing ratio with no delayed fracture occurrences after cup forming is more superior, formability is considered to be superior.

[0069] Hereinafter, the lean duplex stainless steel having a superb drawing property will be described in detail.

[0070] Specimens of lean duplex stainless steel in the composition ratios of the components according to the present disclosure were prepared, and formability was measured by controlling a phase fraction of the materials through carrying out cold annealing after carrying out hot rolling, hot annealing and cold rolling. The following [Table 1] shows alloy compositions (weight %) for the test steel types.

TABLE 1

Steel Type	Cr	Mn	Ni	Si	C	N
Comparative Steel 1	19.20	2.2	0.7	0.5	0.060	0.23
Comparative Steel 2	19.20	3.6	0.7	0.5	0.060	0.19
Present Disclosure Steel 1	20.30	3.05	0.8	0.82	0.021	0.25
Present Disclosure Steel 2	20.19	3.15	1.103	0.66	0.028	0.28
Present Disclosure Steel 3	19.38	2.8	1.023	0.9	0.029	0.283
Present Disclosure Steel 4	20.55	3.3	0.7	1.209	0.048	0.260

[0071] Some of the test steel types of [Table 1] were cold rolled after hot rolled and hot annealed to be prepared into a thin sheet (1.0 t or less). The prepared cold-rolled material was cold annealed at the temperatures shown below, and phase fractions (austenite, ferrite) of the annealed material, various initial deformation temperatures applying 0.3 true strain, Md_SIM10, and a limit drawing ratio measured from the presence of cracks produced in a cup formed after a cup drawing test carried out using the method illustrated in FIG. **1** and leaving the cup attended for 24 hours at room temperature were determined.

[0072] As shown in FIG. **2**, it was seen that strain-induced martensite reached 10% in Comparative Steel 1 near 5° C., and strain-induced martensite reached 10% near −6° C. in Present Disclosure Steel 1 that was annealed at 1100° C., and martensite reached 10% near −18° C. in Present Disclosure Steel 4 that was cold annealed at 1100° C.

[0073] Table 2 shows ferrite and austenite fractions, a maximum limit drawing ratio having no delayed fracture occurrences, and Md_SIM10 of comparative steel and steel of the present disclosure.

TABLE 2

Steel Type	Heat Treatment Temperature (° C.)	Ferrite Fraction (%)	Austenite Fraction (%)	Limit Drawing Ratio	Occurrence of Delayed Fractures	Md_SIM10
Comparative Steel 1	950	70	30	1.9	Occurred	5
	1000	78	22	2	Occurred	10
	1100	83	17	2	Occurred	12
Comparative Steel 2	950	45	55	2.04	Occurred	10
	1000	32	68	2.06	Occurred	20
	1100	35	65	2.06	Occurred	22
Present Disclosure Steel 1	950	31	69	2.18	Not Occurred	−22
				2.2	Occurred	
	1000	35	65	2.18	Not Occurred	−15
				2.22	Occurred	
	1100	36	64	2.18	Not Occurred	−6
				2.2	Occurred	
Present Disclosure Steel 2	950	33	67	2.18	Not Occurred	−18
	1000	37	63	2.2	Occurred	−10
				2.24	Occurred	
	1100	41	59	2.18	Not Occurred	−2
Present Disclosure Steel 3	950	42	58	2.2	Occurred	−10
				2.18	Not Occurred	
				2.2	Occurred	
	1000	40	60	2.18	Not Occurred	−8
				2.2	Occurred	
	1100	43	57	2.18	Not Occurred	−8
				2.2	Occurred	
Present Disclosure Steel 4	950	38	62	2.18	Not Occurred	−25
				2.2	Occurred	
	1000	53	47	2.18	Not Occurred	−18
				2.2	Occurred	
	1100	48	52	2	Not Occurred	−18
				2.2	Occurred	
	1200	52	48	2.12	Not Occurred	−30

[0074] As shown in Table 2, it was seen that the lean duplex stainless steel having a superb drawing property of the present disclosure had changes in the phase fraction depending on the alloy components and the heat treatment temperatures.

[0075] In the steel of the present disclosure, it was seen that the ferrite phase fraction was in the range of 30% to 60%, and the austenite phase fraction was in the range of 70% to 40% when heat treated in the range of 950° C. to 1200° C.

[0076] Ferrite and austenite phase fractions are shown when heat treating Present Disclosure Steel 4 at 950° C., 1000° C., 1100° C. and 1200° C. It was seen that, in Present Disclosure Steel 1 to Present Disclosure Steel 4, the ferrite phase fraction was in the range of approximately 30% to 60% and the austenite phase fraction was in the range of 70% to 40%.

[0077] As shown in FIG. **3** and FIG. **4**, it was seen that, when the Md_SIM10 value was in the range of −30° C. to 0° C., the limit drawing value was greater than 2.08, a value corresponding to a limit drawing value of 304 steel, and delayed fractures did not occur as well.

[0078] Furthermore, it was seen that, when the Md_SIM10 value was in the range of −30° C. to 0° C., the limit drawing value corresponded to a value between 2.12 and 2.18, which was improved compared to 304 steel, and delayed fractures did not occur as well, and strength and elongation of the material was further improved compared to when the Md_SIM10 value was less than −30.

[0079] Technological ideas of the present disclosure have been specifically described according to the preferred embodiments, however, the embodiments are for illustrative purposes only and not to limit the present disclosure. In addition, those skilled in the art will understand that various modifications may be made within the scope of technological ideas of the present disclosure. The scope of a right for the present disclosure described above is defined in the attached claims, and is not bound to the descriptions in the body text of the specification, and all modifications and changes belonging to the range of equivalents of the claims belong to the scope of the present disclosure.

[Reference Numeral]	
1: Die	3: Holder
5: Punch	S: Material

1. Lean duplex stainless steel having a superb drawing property comprising, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2%, and the remainder of Fe and other inevitable impurities,

wherein, as annealed dual-phase steel of ferrite and austenite, Md_SIM10 corresponding to a temperature measured when an amount of strain-induced martensite formed after 0.3 true strain reaches 10%, and a limit drawing ratio (LDR) satisfy the following expressions:

$$-30° \text{ C.} \leq \text{Md\_SIM10} \leq 0° \text{ C.} \quad \text{(expression 1)}$$

$$2.08 \leq \text{LDR} \leq 2.18 \quad \text{(expression 2).}$$

2. The lean duplex stainless steel having a superb drawing property of claim **1**, wherein an austenite fraction satisfies the following range, and the rest is formed with the ferrite.

$$30 \leq \text{-austenite fraction } (\gamma) \leq 70$$

3. A method for producing lean duplex stainless steel having a superb drawing property, the method comprising cold annealing steel including, in weight %, C: 0.02% to 0.08%, Si: 0.5% to 1.3%, Mn: 2.5% to 3.5%, Cr: 19% to 21%, Ni: 0.6% to 1.2%, N: 0.2% to 0.3%, Cu: 0.5% to 1.2% and the remainder of Fe and other inevitable impurities in a range of 950° C. to 1100° C.

* * * * *