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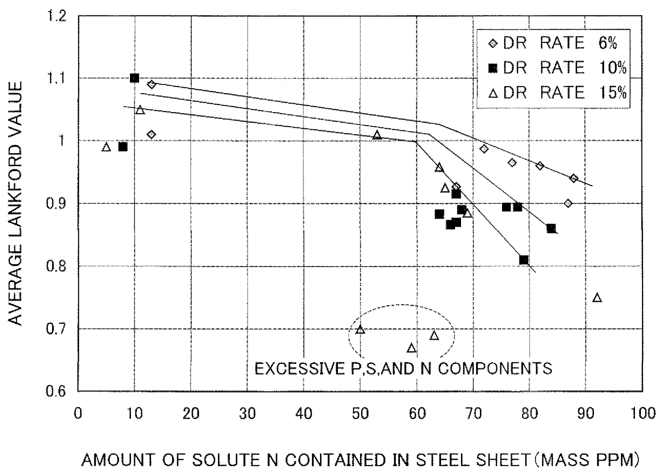
(54) DR STEEL SHEET AND PROCESS FOR MANUFACTURING THE SAME

(57) This DR steel sheet includes the following steel components: C: 0.02 to 0.06 mass%, Si: equal to or less than 0.03 mass%, Mn: 0.05 to 0.5 mass%, P: equal to or less than 0.02 mass%, S: equal to or less than 0.02 mass%, Al: 0.02 to 0.10 mass%, and N: 0.008 to 0.015 mass%. The amount of solute N (Ntotal-NasAIN) in the steel sheet containing a residual iron and inevitable impurities, is equal to or more than 0.006%; and the total stretchability in a rolling direction after aging is equal to or more than 10%, total stretchability in a sheet width direction after aging is equal to or more than 5%, and an average Lankford value after aging is equal to or less than 1.0.

FIG. 4



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Description

[Technical Field]

[0001] The present invention relates to a DR (Double Reduced) steel sheet for EOE (Easy Open End) which enables an easy-opening by hand of a portion of a can cover that is widely used for a drink can, a food can and the like, and to a manufacturing method thereof.
The present application is based on Japanese Patent Application No. 2006-219066, and the contents of which are incorporated herein by reference.

[Background Art]

[0002] A can cover having an easy-open function is being widely used for a metal can. Such a can cover generally includes a partial-open type can cover that is mainly used for a drink can, and a full-open type can cover that is mainly used for a food can. Both types of can covers generally employ an easy-open function in which an opening formed in a can cover panel is broken by pulling up a tab fixed by a rivet.
[0003] In a body of an easy-open can cover are formed with a rivet and an opening guide groove, which are not provided on a can cover having no easy-open function.
[0004] The opening guide groove is formed to a depth of above 1/2 of thickness of a can cover plate by pressing a surface of the can cover with high load using a working tool having a knife-shaped projection formed in a predetermined opening contour.
[0005] The rivet is formed by a combined process of stretching and drawing. The formed rivet is inserted in a hole provided in the tab, and then, a rivet mechanism is formed by performing a caulking process to a resultant structure.
[0006] As a material for the aforementioned easy-open can cover, a tine, a surface-treated steel sheet, such as an electrolytic chromium coat steel sheet, and an aluminum steel sheet are used. Typically, a coated material is used to protect contents in a can, although an uncoated tin may be used for, for example, a fruit can.
[0007] In recent years, it has been considered to use a thin hard material for the purpose of reducing material costs for easy-open can covers, as same as previous can bodies and common can covers. For example, as disclosed in the following Patent Document 1 for example, when the thickness of a steel sheet is limited to equal to or more than 0.15 mm and less than 0.23, bending resistance in opening an easy-open cover may be reduced, thereby improving can cover openability. In addition, as disclosed in the following Patent Document 2, low carbon steel is advantageous over extra-low carbon steel in terms of component of an easy-open can cover, and the can cover openability can be improved by subjecting a box annealing method to the easy-open can cover at a high reduction rate of 2 to 10%.
[0008] These documents aim to improve the can openability but have a problem of poor cover manufacturability. The following Patent Document 3 discloses a technique in which B oxide is used to realize achieving both of the can openability and the cover manufacturability. The following Patent Document 3 states that: a starting point of a void in a steel sheet facilitates opening of a can; and rivet formability is not deteriorated by limiting a size of B oxide. However, since impurities such as oxide existing in steel may be a starting point of breakage due to working, Patent Document 3 does not present a substantial solution for this problem. The above-mentioned suggestions have not been put into practical use since a thin hard material has cracks produced in a rivet forming process. On the other hand, the following Patent Document 4 discloses a complex stretching process using bending and bending-back with three or more steps. The hard material has bee put into practical use in combination with such a multi-step complex stretching process.
[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. S63-109121
[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. S64-015326
[Patent Document 3] Japanese Unexamined Patent Application, First Publication No. H10-251799
[Patent Document 4] French Patent, Publication No. FR9004264

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0009] As described above, the use of the thin hard material is likely to produce cracks in stretching in the typical rivet forming process. It could be estimated that this is due to insufficient material stretchability. In order to make up for the insufficient material stretchability, the rivet forming process including the complex stretching using the multi-step bending and bending-back was required. It is believed that the multi-step bending and bending-back gives the effect of increasing a limitative drawing ratio and stretching a material by the bending and bending-back, and thereby enabling the rivet forming.
[0010] However, the conventional production facilities have only a two-step working space. Accordingly, a pressing

machine and a mould have to be newly established for a three or more step working, and thereby requiring high expenses.

[0011] The present invention was made in view of the above-mentioned circumstances and has an object of providing a DR steel sheet with excellent rivet workability which enables EOE working even with the conventional production facility used for a two step rivet forming process, and a manufacturing method of the DR steel sheet at low costs. [Means for Solving the Problems]

[0012] As a result of inventors' studies for resolving the aforementioned problems, the present invention provides a DR steel sheet and a manufacturing method thereof, which are inexpensive and are capable of restricting an average Lankford value after an aging process by limiting a steel component and securing total stretchability in a rolling direction and a sheet width direction after the aging process. The gist of the present invention is as follows.

(1) A DR steel sheet of the present invention includes the following steel components: C: 0.02 to 0.06 mass%, Si: equal to or less than 0.03 mass%, Mn: 0.05 to 0.5 mass%, P: equal to or less than 0.02 mass%, S: equal to or less than 0.02 mass%, Al: 0.02 to 0.10 mass%, and N: 0.008 to 0.015 mass%. The amount of solute N (Ntotal-NasAlN) in the steel sheet containing a residual iron and inevitable impurities, is equal to or more than 0.006%; and the total stretchability in a rolling direction after aging is equal to or more than 10%, total stretchability in a sheet width direction after aging is equal to or more than 5%, and an average Lankford value after aging is equal to or less than 1.0.

(2) A manufacturing method of a DR steel sheet of the present invention including the following steel components: C: 0.02 to 0.06 mass%, Si: equal to or less than 0.03 mass%, Mn: 0.05 to 0.5 mass%, P: equal to or less than 0.02 mass%, S: equal to or less than 0.02 mass%, Al: 0.02 to 0.10 mass%, and N: 0.008 to 0.015 mass%, wherein: the amount of solute N (Ntotal-NasAlN) in the steel sheet containing a residual iron and inevitable impurities, is equal to or more than 0.006%; and the total stretchability in a rolling direction after aging is equal to or more than 10%, total stretchability in a sheet width direction after aging is equal to or more than 5%, and an average Lankford value after aging is equal to or less than 1.0. The manufacturing method includes: heating a steel work piece at equal to or more than 1200 °C, and then hot-rolling the steel work piece at a finishing temperature of equal to or more than an Ar3 transformation point; forming a winding hot-rolled steel sheet at a winding temperature of equal to or less than 600 °C; subjecting a cold rolling to the wind hot-rolled steel sheet with a rolling rate of equal to or more than 80% after acid washing; subjecting annealing to the cold-rolled steel sheet at a temperature of equal to or more than a recrystallization temperature and equal to or less than an Ac1 transformation point; and subjecting DR rolling to the annealed steel sheet with a tempering rolling rate of 6% to 15%.

[Effects of the Invention]

[0013] While the conventional thin continuous annealed DR steel sheets require a rivet forming process in three steps or more, the DR steel sheet of the present invention enables a rivet forming process in two steps by: improving the steel components and the manufacturing method thereof; and specifying the total stretchability in the rolling direction and in the rolling sheet width direction after aging, and specifying the Lankford value after stretching after aging.
As a result, it is possible to use materials with saved resources and energy without requiring additional expensive facilities, which results in energy saving in an EOE manufacturing process, thereby exerting the extremely useful effects in the industrial applicability.

[Brief Description of the Drawings]

[0014]

FIG. 1 is a sectional view after a first step of rivet forming.
FIG. 2 is a sectional view after a second step of rivet forming.
FIG. 3 is a sectional view after rivet caulking, where the reference symbol t denotes a tab while the reference symbol d represents a rivet diameter.
FIG. 4 is a graph showing a relationship between a solute N and a Lankford value.

[Best Mode for Carrying Out the Invention]

[0015] An embodiment of a DR steel sheet and a manufacturing method thereof according to the present invention will be explained below.
The present invention relates to a DR steel sheet and a manufacturing method thereof, which are inexpensive and are capable of restricting an average Lankford value after an aging process by limiting steel components and securing the total stretchability in a rolling direction and a sheet width direction after the aging process.

(About Mechanical Property)

[0016] The present invention is on the assumption that rivet formation is achieved in two steps. A section in a forming process is shown as follows. That is, FIG 1 shows a sectional view after stretching at a first step, FIG. 2 shows a sectional view after rivet forming by drawing at a second step, and FIG. 3 shows a sectional view of a rivet mechanism obtained by the caulking.

[0017] To begin with, the rivet forming requires a characteristic that follows processing. The inventors have found that the total stretchability of equal to or more than 10% in a rolling direction after an aging process and stretchability of equal to or more than 5% in a sheet width direction after the aging process follow the rivet forming smoothly. The reason why it could follow the rivet forming is unclear in spite of the smaller total stretchability in the rolling direction comparing to the total stretchability in the sheet direction. However, it is believed that drawing included in the rivet forming has an effect on a Lankford value. In other words, it is known that the Lankford value in the sheet width direction increases over that in the rolling direction in a steel sheet having the Lankford value of less than 1.0. Accordingly, processing in the sheet width direction may have the same possibility as working in the rolling direction as total stretchability interacts with the Lankford value complementarily. On the other hand, if the total stretchability in the rolling direction after the aging process is less than 10% or the total stretchability in the sheet width direction after the aging process is less than 5%, a material will be broken at the time of stretching at a first step or drawing at a second step.

[0018] In addition, a rivet diameter is important in caulking with a tab. If the rivet diameter is small, the tab may be detached. The inventors have found that a steel sheet with a caulked tab is different in an average Lankford value after an aging process from a steel sheet with a detached tab. If the average Lankford value exceeds 1.0, the rivet diameter becomes small. On the contrary, if the average Lankford value is equal to or less than 1.0, the rivet diameter becomes large and the tab is not detached. Although the reason for this is unclear, it is believed that a uniform large rivet diameter is obtained as a Lankford value in a rolling direction having high stretchability becomes small and a Lankford value in a sheet width direction having low stretchability becomes large, thereby making plastic mobility of a steel sheet equal, if the average Lankford value is equal to or less than 1.0. The inventors have made the present invention based on the above, although the Lankford values in the rolling direction and the sheet width direction are empirically estimated because measurement for the Lankford value of a thin hard steel sheet shows only an average Lankford value calculated based on a Young's modulus of the steel sheet.

[0019] In addition, an aging process, which is generally carried out at 180 to 220°C (200 to 210°C) for 7 to 30 minutes, is carried out at 210°C for 30 minutes in an evaluation test.

[0020] The important thing is to provide a method of achieving the aforementioned material property in a continuous annealing DR steel sheet which can be inexpensively manufactured using a thin steel sheet material. Next, components of the DR steel and a manufacturing method thereof will be described.

(About Steel Components)

<C: 0.02 mass% to 0.06 mass%>

[0021] C is one of factors that dominate crystalline grain growth. As the addition amount of C decreases, coarsening of crystalline grains of a hot rolling steel sheet and grain growth in annealing are accelerated, thereby raising the average Lankford value (r value) of the steel sheet. Accordingly, the lower limit of the amount of C needs to be less than 0.02% in order to make an r value equal to or less than 1.0. On the other hand, as the amount of C increases, the crystalline grains become refined and much cementite is extracted from steel. The refined grains and the extracted cementite, which are the starting point of void generation in a tensile test, facilitate propagation of cracks, thereby making the total stretchability of a product sheet small. Accordingly, the upper limit of the amount of C is set to be 0.06%.

<Si: equal to or less than 0.03 mass%>

[0022] Since the large addition amount of Si may cause plating and abrasion-resistance deterioration, it is preferable that the addition amount of Si is small. However, since Si is an element to be inevitably mixed in a refining process and since no practical problem occurs if Si is small in amount. Therefore, the upper limit of the amount of Si is set to be 0.03%. In case of need for excellent abrasion-resistance, it is preferable to set the upper limit of the amount of Si to be equal to or less than 0.02%.

<Mn: 0.05 mass% to 0.5 mass%>

[0023] Mn is an element useful for preventing red brittleness in a hot rolling with S fixed. To achieve this effect, Mn is necessarily added by double or more of the addition amount of S. Accordingly, when the addition amount of S is equal to or less than 0.02%, the lower limit of the amount of Mn has to be less than 0.05%. On the other hand, crystalline grains are apt to be granulized in a steel sheet that contains a quantity of Mn, which may result in hardness and deterioration of stretchability. In addition, since Mn is enriched on a surface of a steel sheet by a heat treatment, which may result in deterioration of abrasion-resistance, the upper limit of the amount of Mn is set to be 0.5%.

<P: equal to or less than 0.02 mass%>

[0024] Like Mn, P makes a steel sheet hard to thereby deteriorate the total stretchability and abrasion-resistance. In particular, if the amount of P exceeds 0.02%, segregation of crystalline grains is remarkable, which may result in brittleness of a steel sheet and difficulty in obtaining the required total stretchability. Accordingly, the upper limit of the amount of P is set to be 0.02%.

<S: equal to or less than 0.02 mass%>

[0025] S exists as an intervenient and is a useless element causing deterioration of the total stretchability and abrasion-resistance. Accordingly, the less amount of S is more preferable. However, since S is an element to be inevitably mixed in a refining process and since no practical problem occurs if S is small in amount, the upper limit of the amount of S is set to be 0.02%.

<Al: 0.02 mass% to 0.10 mass%>

[0026] Al is an element which is required as a deoxidizer in producing a solution and is preferably used to increase purity of a steel sheet. Accordingly, the addition amount of Al has to be sufficient to exclude oxygen from steel. If the amount of Al is small, deoxidization is insufficient, which may result in increase of an intervenient in steel and hence deterioration of total stretchability like cementite. Accordingly, the lower limit of the amount of Al is set to be 0.02%. On the other hand, if the amount of Al is large, excessive Al after deoxidization is combined with N in steel to be AlN extract, which may decrease the total stretchability and cause surface defects due to alumina cluster or the like. Accordingly, the upper limit of the amount of Al is set to be 0.10%.

<N: 0.008 mass% to 0.015 mass%>

[0027] In the present invention, N is the most important factor in manufacturing a steel sheet and exerts the effect of the present invention by acting on the steel sheet as solute N. The solute N is defined by the amount of solute N = Ntotal - NasAIN, that is, a value obtained by subtracting the amount of extracted N (=AIN) measured using a melting method by bromide ester from the total amount ofN (=Ntotal) included in the steel sheet. N is a solid solution-reinforced element, which is superior to P, and does not deteriorate abrasion-resistance unlike P. In addition, N reduces the average Lankford value of a product sheet by acting on an aggregate important in the present invention. However, since the effect of solute N can not be expected if the amount of solute N is less than 0.006%, the lower limit of the total amount of N (=Ntotal) is set to be less than 0.008%. On the other hand, if the amount of solute N exceeds 0.015%, brittleness of the steel sheet becomes remarkable, which may result in alleviation of total stretchability and porosity defect due to slab cracks or gas produced in a continuous casting process. Accordingly, the upper limit of the amount ofN is set to be 0.015%, but in consideration of material stability and good yield in a series of manufacturing processes, it is preferable that the upper limit of the amount of N is set to be 0.010%.

<Other Chemical Components>

[0028] As described above, the EOE DR steel sheet contains the following components: C: 0.02 to 0.06 mass%, Si: equal to or less than 0.03 mass%, Mn: 0.05 to 0.5 mass%, P: less than 0.02 mass%, S: equal to or less than 0.02 mass%, Al: 0.02 to 0.10 mass%, and N: 0.008 to 0.015 mass%. However, the steel sheet may contain elements commonly existing in a known DR steel sheet for a welded can. For example, the steel sheet may contain the following components: Cr; equal to or less than 0.10 mass%, Cu: equal to or less than 0.20 mass%, Ni: equal to or less than 0.15 mass%, Mo: equal to or less than 0.05 mass%, B: less than 0.0020 mass%, one or two or more of Ti, Nb, Zr, V and so on: less than 0.3 mass%, Ca: equal to or less than 0.01 mass%, and the like, depending on its purpose.

<Manufacture Conditions>

[0029] A steel work piece as a rolling material is not particularly limited, but is preferably obtained using a continuous casting method in order to minimize macro segregation. Since the continuous work piece does not always need cooling before being hot-rolled, the continuous steel work piece is preferably cast, hot-rolled and directly inserted into a heating furnace. This is for preventing available solute N from decreasing due to cooling of the steel work piece. Although a detailed mechanism is unclear, it is proved that if a steel work piece is cooled and re-heated, the amount of solute N decreases in accordance with decreasing temperature. Accordingly, when a cooled steel work piece is re-heated, it is preferable to apply heating temperature of the process capability upper limit to close to situation of a casting process. In the present invention, it is necessary to re-heat the cooled steel work piece with heating temperature of at least equal to or more than 1200°C.

[0030] Finishing hot rolling is carried out with temperature of the steel work piece keeping at above an Ar3 transformation point. By performing rolling process at above the transformation point enables obtaining a uniform and fine hot rolling structure. Furthermore, by suppressing the distortion induced extraction of AlN, it is possible to easily secure a quantity of stable solute N in a hot rolling step.

[0031] After the finishing the hot rolling, the AlN extraction is reduced by forcedly water-cooling the steel work piece. In the present invention, since it is necessary to secure a quantity of solute N in the hot rolling step, the cooling after the finishing hot rolling is carried out as quickly as possible, and winding temperature is set to be equal to or less than 600°C. The reason for this is that the solute Al not used for deoxidization in steel is likely to combine with N in a temperature range from a point immediately before an Ar3 transformation point to a point exceeding 600°C, and it is very preferable that the steel sheet passes through this temperature range in a short time to prevent the solute N from being reduced due to increased generation of AlN.

[0032] The hot-rolled steel sheet obtained as above is subjected to a descaling step using acid washing, and then to a cold rolling step. If a cold rolling rate is less than 80%, the average Lankford value may exceed 1.0 due to remarkable grain growth in a continuous annealing step. Accordingly, the cold rolling rate is preferably somewhat equal to or more than 80%, more preferably 80% to 95%.

[0033] A recrystallizing step after the cold rolling is carried out in an annealing furnace. If annealing temperature exceeds an Ac1 transformation point, the average Lankford value of a product plate exceeds 1.0 due to remarkable grain growth. Accordingly, the upper limit of the annealing temperature is set to be 700°C. On the other hand, a cold rolling structure remains at below recrystallization temperature, thereby making it impossible to secure total stretchability. Accordingly, the lower limit of the annealing temperature is set to be equal to or more than the recrystallization temperature.

[0034] A secondary cold rolling after the annealing is a important factor in manufacturing the steel sheet of the present invention, next to the solute N. A reduction rate of 6% to 15% is applied to the continuous annealed steel sheet including the solute N of equal to or more than 0.006% of the present invention. This condition allows suppression of deterioration of the total stretchability due to work strengthening and secure of anisotropy of stretchability of a steel sheet, that is, secure of stretchability of equal to or more than 10% in a rolling direction and equal to or more than 5% in a sheet width direction. Although a detailed mechanism is unclear, if the solute N in steel is equal to or more than 0.006%, there is a possibility in that it acts on the density and the movement of dislocations generated by rolling, thereby preventing forming cells. The lower limit of the optimal reduction rate is 6%. In rolling at less than this lower limit of the optimal reduction rate, a stable property of rolling is lost while the total stretchability increases, thereby making it impossible to secure steel sheet flatness required for coating and continuous manufacture of can covers. On the other hand, if the reduction rate exceeds 15%, anisotropy of stretchability of the steel sheet increases to turn the dislocations into cells, thereby making the stretchability in the sheet width direction less than 5%. Accordingly, the upper limit of the reduction rate has to be 15%. The steel sheet subjected to the above-mentioned processes is taken as a final product. Sheet thickness of the final product is not particularly limited. However, since the stretchability is in proportion to the sheet thickness, the upper limit of the sheet thickness is preferably 0.20 mm in consideration of the costs of a can body after manufacture of a can. If the sheet thickness is less than 0.14 mm, the workability and the strength of a can cover are likely to be insufficient. Accordingly, the practical lower limit of the sheet thickness is preferably 0.14 mm. A surface treatment for the steel sheet is not particularly limited as long as it can be applied to a steel sheet for typical cans. That is, a surface treatment may be carried out for the steel sheet using a tin plating, a chromium plating, a nickel plating, combinations thereof, or the like. In addition, the present invention is also applicable to a precoating steel sheet manufactured by attaching a coat or an organic resin film to any of the aforementioned plated steel sheet.

[Examples]

[0035] Hereinafter, examples of the present invention will be described in comparison to comparative examples. Table 1 shows components, properties, and rivet workability of steel sheets, and Table 2 shows manufacture conditions, properties, and rivet workability of steel sheets. The manufacturing conditions for the steel materials shown in Table 1 are as follows; heating temperature of a steel work piece: 1211°C to 1248°C, finishing temperature of hot rolling: 851°C to 896°C, winding temperature: 546°C to 599°C, cold rolling rate: 88.2% to 92.6%, continuous annealing temperature: 642°C to 686°C, tempering rolling rate: 6% to 15%, and product sheet thickness: 0.160 mm to 0.200 mm. The steel materials shown in Table 2 are manufactured using the same steel work pieces as Example 2 shown in Table 1. An Ar3 transformation point of Example 2 is obtained by putting steel components; C: 0.041 mass%, Mn: 0.28 mass%, P: 0.012 mass% and Al: 0.059 mass%, into an equation: Ar3=850-660C-120Mn+1770P+400Al. The obtained Ar3 transformation point of the Example 2 is 834°C. Comparative Examples 23 to 28 are SR (Single Reduce) materials, other comparative examples and examples are DR steel sheets having product sheet thickness of 0.168 mm to 0.200 mm. Surfaces of these steel sheets are subjected to an electrolytic chromium process or a Sn plating process and then a chemical treatment. Subsequently, outer and inner surfaces are in turn coated (at dry film thickness of 10 μm) and then baked (at 190°C for 10 minutes).

[0036] In addition, for the rivet workability, a full-open EOE having ϕ301 (a can having an inner diameter of 74.1 mm) is prepared through two-processes of rivet forming. Cracks in the rivet forming process are evaluated by naked eyes and a rivet diameter in a caulking process is measured. Results of general evaluation for the rivet workability are listed in Tables 1 and 2. FIG. 4 is a graph showing the relationship between the solute N and the Lankford value.

[0037] It was confirmed that the examples satisfying the conditions of the present invention have good rivet workability and exert the effects of the present invention. In addition, as shown in FIG. 4, when the solute N included in the steel sheet is equal to or more than 0.006%, it strongly acts on an aggregate, thereby making the average Lankford value of the steel sheet equal to or less than 1.0. The average Lankford value further decreases in combination with a high DR rolling rate.

[0038]

Table 1

	Chemical components (mass%), Solute N (ppm)								Property after aging				Product Sheet thickness (mm)	Rivet workability			DR rate (%)
	C	Si	Mn	P	S	Al	N	Product Solute N	Stretchability in rolling direction (%)	Stretchability in sheet width direction (%)	Average *r* value	HR30T		Rivet forming process	Rivet caulking process	General evaluation	
Example 1	0.022	0.007	0.07	0.005	0.009	0.027	0.0082	66	16	14	0.866	68	0.168	No crack	Good caulking	Good	10
Example 2	0.041	0.019	0.28	0.012	0.013	0.059	0.0110	67	13	7	0.915	69	0.183	No crack	Good caulking	Good	10
Example 3	0.059	0.024	0.54	0.020	0.019	0.099	0.0143	68	15	7	0.89	72	0.200	No crack	Good caulking	Good	10
Example 4	0.046	0.027	0.25	0.020	0.006	0.038	0.0086	67	16	8	0.87	73	0.200	No crack	Good caulking	Good	10
Example 5	0.038	0.006	0.05	0.014	0.007	0.044	0.0113	82	16	10	0.96	68	0.183	No crack	Good caulking	Good	6
Example 6	0.038	0.008	0.52	0.017	0.015	0.046	0.0111	88	17	8	0.94	67	0.183	No crack	Good caulking	Good	6
Example 7	0.045	0.005	0.25	0.024	0.006	0.040	0.0120	84	17	8	0.86	69	0.200	No crack	Good caulking	Good	10
Example 8	0.037	0.007	0.22	0.016	0.024	0.046	0.0108	79	12	8	0.81	70	0.160	No crack	Good caulking	Good	10
Example 9	0.043	0.007	0.31	0.013	0.014	0.024	0.0088	67	12	8	0.927	70	0.183	No crack	Good caulking	Good	6
Example 10	0.041	0.008	0.28	0.012	0.003	0.095	0.0102	77	16	13	0.965	68	0.183	No crack	Good caulking	Good	6
Example 11	0.044	0.008	0.31	0.013	0.015	0.026	0.0083	64	14	10	0.883	70	0.183	No crack	Good caulking	Good	10
Example 12	0.049	0.010	0.24	0.013	0.012	0.050	0.0147	92	12	5	0.75	70	0.190	No crack	Good caulking	Good	15
Example 13	0.041	0.009	0.28	0.012	0.003	0.059	0.0102	64	12	5	0.958	70	0.183	No crack	Good caulking	Good	15
Example 14	0.044	0.008	0.31	0.013	0.015	0.024	0.0080	69	11	6	0.885	71	0.183	No crack	Good caulking	Good	15
Example 15	0.043	0.008	0.51	0.013	0.014	0.026	0.0087	65	13	5	0.925	71	0.183	NO crack	Good caulking	Good	15

(continued)

	Chemical components (mass%), Solute N (ppm)								Property after aging				Product Sheet thickness (mm)	Rivet workability			DR rate (%)
	C	Si	Mn	P	S	Al	N	Product Solute N	Stretchability in rolling direction (%)	Stretchability in sheet width direction (%)	Average *r* value	HR30T		Rivet forming process	Rivet caulking process	General evaluation	
Example 16	0.040	0.007	0.21	0.011	0.003	0.047	0.0087	72	17	9	0.987	68	0.168	No crack	Good caulking	Good	6
Comparative Example 1	0.019	0.006	0.22	0.016	0.007	0.043	0.0054	11	11	3	1.05	72	0.200	Crack in second process		Bad	15
Comparative Example 2	0.066	0.008	0.22	0.012	0.009	0.049	0.0091	78	13	2	0.894	71	0.168	Crack in second process		Bad	10
Comparative Example 3	0.038	0.038	0.22	0.016	0.015	0.045	0.0149	87	16	4	0.90	68	0.168	Crack in second process		Bad	6
Comparative Example 4	0.037	0.007	0.21	0.012	0.009	0.047	0.0097	76	14	4	0.894	70	0.168	Crack in first process		Bad	10
Comparative Example 5	0.003	0.001	0.56	0.012	0.005	0.056	0.0022	1	5	2	1.25	72	0.183	Crack in first process		Bad	15
Comparative Example 6	0.045	0.011	0.23	0.025	0.013	0.053	0.0109	59	1	3	0.67	74	0.200	Crack in first process		Bad	15
Comparative Example 7	0.045	0.012	0.23	0.014	0.025	0.054	0.0114	50	1	1	0.70	73	0.200	Crack in first process		Bad	15
Comparative Example 8	0.041	0.006	0.24	0.011	0.005	0.013	0.0019	8	14	4	0.99	69	0.168	Crack in first process		Bad	10
Comparative Example 9	0.042	0.005	0.22	0.015	0.007	0.141	0.0059	13	20	12	1.01	69	0.200	No crack	Rivet diameter small	Bad	6
Comparative Example 10	0.044	0.006	0.22	0.015	0.007	0.042	0.0058	13	18	9	1.09	69	0.200	No crack	Rivet diameter small	Bad	6
Comparative Example 11	0.046	0.011	0.23	0.014	0.014	0.053	0.0156	63	1	1	0.69	74	0.200	Crack in first process		Bad	15

(continued)

	Chemical components (mass%), Solute N (ppm)								Property after aging				Product Sheet thickness (mm)	Rivet workability			DR rate (%)
	C	Si	Mn	P	S	Al	N	Product Solute N	Stretchability in rolling direction (%)	Stretchability in sheet width direction (%)	Average *r* value	HR30T		Rivet forming process	Rivet caulking process	General evaluation	
1 Comparative Example 12	0.046	0.011	0.23	0.014	0.013	0.053	0.0118	53	1	1	1.01	72	0.200	Crack in first process		Bad	15
comparative Example 13	0.044	0.006	0.22	0.016	0.007	0.043	0.0059	10	8	5	1.10	72	0.200	Crack in second process		Bad	10
Comparative Example 14	0.018	0.004	0.23	0.012	0.006	0.036	0.0019	5	12	4	0.99	69	0.183	Crack in first process		Bad	15
Comparative Example 15	0.004	0.001	0.54	0.013	0.006	0.062	0.0018	1	5	1	1.36	70	0.168	Crack in first process		Bad	15
Comparative Example 16	0.034	0.014	0.27	0.015	0.014	0.048	0.0062	40	29	20	0.88	62	0.200			Bad	1
Comparative Example 17	0.034	0.014	0.27	0.015	0.014	0.048	0.0062	35	27	22	0.86	62	0.200			Bad	1
Comparative Example 18	0.034	0.014	0.27	0.015	0.014	0.048	0.0062	37	25	16	0.87	63	0.200			Bad	1
Comparative Example 19	0.032	0.013	0.27	0.015	0.014	0.047	0.0061	39	26	17	0.80	65	0.204			Bad	1
Comparative Example 20	0.032	0.013	0.27	0.015	0.014	0.047	0.0061	34	26	25	0.82	64	0.204			Bad	1
Comparative Example 21	0.032	0.013	0.27	0.015	0.014	0.047	0.0061	33	25	11	0.86	64	0.204			Bad	1
Note: Underlined ones indicate departing from the scope of the present invention.																	

[0039]

Table 2

	Hot rolling			Cold rolling	Continuous annealing	DR rolling	Product Sheet thickness (mm)	Rivet workability			Remarks
	Heating temperature (°C)	Finishing temperature (°C)	Winding temperature (°C)	Rolling rate (%)	Annealing temperature (°C)	Tempering rolling rate (%)		Rivet forming process	Rivet caulking process	General evaluation	
Example 17	1201	872	559	91.9	628	10	0.183	No crack	Good caulking	Good	
Example 18	1239	853	559	91.9	628	10	0.183	No crack	Good caulking	Good	
Example 19	1247	862	597	88.2	645	15	0.200	No crack	Good caulking	Good	
Example 20	1247	875	568	81.9	647	15	0.200	No crack	Good caulking	Good	
Example 21	1237	881	576	92.2	719	10	0.183	No crack	Good caulking	Good	
Example 22	1237	890	564	91.9	678	6	0.183	No crack	Good caulking	Good	
Example 23	1237	878	589	91.9	674	15	0.183	No crack	Good caulking	Good	
Comparative Example 16	1137	887	558	93.3	651	13	0.200	Crack in second process		Bad	
Comparative Example 17	1238	833	600	88.2	650	15	0.200	Crack in second process		Bad	
Comparative Example 18	1238	888	766	88.2	649	8	0.200	No crack	Rivet diameter small	Bad	
Comparative Example 19	1237	924	580	78.6	677	15	0.200	Crack in first process		Bad	
Comparative Example 20	1265	922	598	91.3	754	15	0.183	No crank	Rivet diameter small	Bad	

(continued)

	Hot rolling			Cold rolling	Continuous annealing	DR rolling	Product Sheet thickness (mm)	Rivet workability			Remarks
	Heating temperature (°C)	Finishing temperature (°C)	Winding temperature (°C)	Rolling rate (%)	Annealing temperature (°C)	Tempering rolling rate (%)		Rivet forming process	Rivet caulking process	General evaluation	
Comparative Example 21	1238	866	598	88.2	646	5	0.200	No crack	diameter small	Bad	Bad shape
Comparative Example 22	1237	912	505	88.2	667	20	0.200	Crack in first process		Bad	
Comparative Example 23	1137	887	558	93.3	651	1.3	0.200			Bad	SR material
Comparative Example 24	1137	886	562		658	1.4	0.200			Bad	SR material
Comparative Example 25	1137	899	567		614	1.2	0.200			Bad	SR material
Comparative Example 26	1137	912	541	93.3	648	1.1	0.204			Bad	SR material
Comparative Example 27	1137	909	566		650	0.9	0.204			Bad	SR material
Comparative Example 28	1137	899	567		653	1.3	0.204			Bad	SR material

Note: Underlined ones indicate departing from the scope of the present invention.
Note: Steel work piece of Example 2 is used.

[Industrial Applicability]

[0040] While the conventional continuous annealed DR steel sheets require a rivet forming process in three steps or more, the DR steel sheet of the present invention enables a rivet forming process in two steps by improving the component composition and the manufacturing method, that ism by specifying the stretching in rolling direction and in the width direction after aging, and the Lankford value after aging.
While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be considered as being limited by the foregoing description, and is only limited by the scope of the appended claims.

Claims

1. A DR steel sheet comprising the following steel components:

C: 0.02 to 0.06 mass%,
Si: equal to or less than 0.03 mass%,
Mn: 0.05 to 0.5 mass%,
P: equal to or less than 0,02 mass%,
S: equal to or less than 0.02 mass%,
Al: 0.02 to 0.10 mass%, and
N: 0.008 to 0.015 mass%,

wherein: the amount of solute N (Ntotal-NasAlN) in the steel sheet containing a residual iron and inevitable impurities, is equal to or more than 0.006%; and
the total stretchability in a rolling direction after aging is equal to or more than 10%, total stretchability in a sheet width direction after aging is equal to or more than 5%, and an average Lankford value after aging is equal to or less than 1.0.

2. A manufacturing method of a DR steel sheet including the following steel components:

C: 0.02 to 0.06 mass%,
Si: equal to or less than 0.03 mass%,
Mn: 0.05 to 0.5 mass%,
P: equal to or less than 0.02 mass%,
S: equal to or less than 0.02 mass%,
Al: 0.02 to 0.10 mass%, and
N: 0.008 to 0.015 mass%,

wherein: the amount of solute N (Ntotal-NasAlN) in the steel sheet containing a residual iron and inevitable impurities, is equal to or more than 0.006%; and
the total stretchability in a rolling direction after aging is equal to or more than 10%, total stretchability in a sheet width direction after aging is equal to or more than 5%, and an average Lankford value after aging is equal to or less than 1.0, the manufacturing method comprising:

heating a steel work piece at equal to or more than 1200 °C, and then hot-rolling the steel work piece at a finishing temperature of equal to or more than an Ar3 transformation point;
forming a winding hot-rolled steel sheet at a winding temperature of equal to or less than 600°C;
subjecting a cold rolling to the wind hot-rolled steel sheet with a rolling rate of equal to or more than 80% after acid washing;
subjecting annealing to the cold-rolled steel sheet at a temperature of equal to or more than a recrystallization temperature and equal to or less than an Ac I transformation point; and
subjecting DR rolling to the annealed steel sheet with a tempering rolling rate of 6% to 15%.

FIG. 1

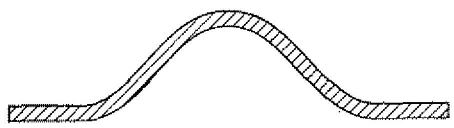


FIG. 2

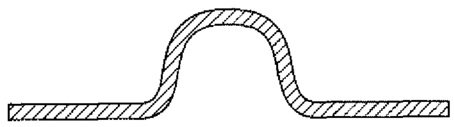


FIG. 3

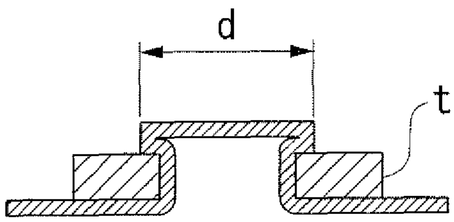
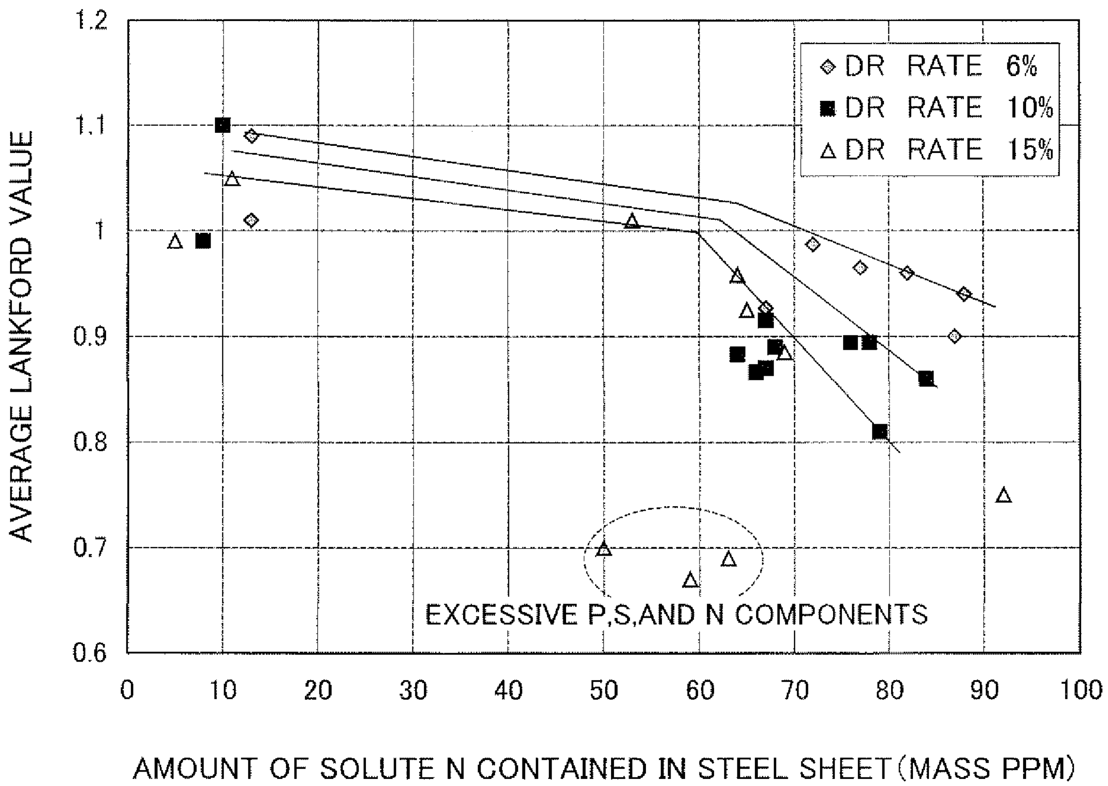


FIG. 4


1.2
1.1
1
0.9
0.8
0.7
0.6
AVERAGE LANKFORD VALUE
DR RATE 6%
DR RATE 10%
DR RATE 15%
EXCESSIVE P,S,AND N COMPONENTS
0
10
20
30
40
50
60
70
80
90
100
AMOUNT OF SOLUTE N CONTAINED IN STEEL SHEET (MASS PPM)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2007/065590

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *B21B1/22*(2006.01)i, *B21B1/28*(2006.01)i, *B21B3/00*(2006.01)i, *C21D9/46*(2006.01)i, *C22C38/06*(2006.01)i

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)
C22C38/00-38/60, C21D9/46-9/48

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

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.
X	JP 10-110238 A (Nippon Steel Corp.), 28 April, 1998 (28.04.98), Table 1 (Family: none)	1,2
A	JP 11-315343 A (Kawasaki Steel Corp.), 16 November, 1999 (16.11.99), Tables 1, 2 (Family: none)	1,2
P,A	JP 2007-177315 A (Nippon Steel Corp.), 12 July, 2007 (12.07.07), Tables 1, 2, 3 (Family: none)	1,2

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

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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
01 November, 2007 (01.11.07)	13 November, 2007 (13.11.07)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

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Patent documents cited in the description

- JP 2006219066 A **[0001]**
- JP S63109121 B **[0008]**
- JP S64015326 B **[0008]**
- JP H10251799 B **[0008]**
- FR 9004264 **[0008]**