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(54) **HIGH-STRENGTH, HIGHLY WORKABLE STEEL SHEET, AND METHOD FOR  
MANUFACTURING SAME**

(57) A high strength and high formability steel sheet contains, by mass% of the steel sheet: greater than 0.020% and less than 0.040% of C; not less than 0.003% and not greater than 0.100% of Si; not less than 0.10% and not greater than 0.60% of Mn; not less than 0.001% and not greater than 0.100% of P; not less than 0.001% and not greater than 0.020% of S; not less than 0.005%

and not greater than 0.100% of Al; and greater than 0.0130% and not greater than 0.0170% of N, wherein a remainder is Fe and inevitable impurities, and the steel sheet has: a tensile strength in a rolling direction of not lower than 520 MPa; an Erichsen value of not less than 5.0 mm; and a resin film layer at least on a side to be an inner surface of a can.

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**Description**

## Field

- 5 **[0001]** The present invention relates to a high strength and high formability steel sheet suitable for application to a steel sheet for easy open ends, and a manufacturing method thereof.

## Background

- 10 **[0002]** Among steel sheets used for beverage cans or food cans, a steel sheet referred to as a double reduced (DR) material may be used for lids, bottoms, bodies of three-pieced cans, drawn cans, or the like. With the DR material manufactured by a DR method of performing cold rolling again after annealing, a sheet thickness can be made thin more easily than with a single reduced (SR) material manufactured only by temper rolling at a small reduction ratio. Thus, it is possible, using the DR material, to reduce costs for manufacturing cans. In the DR method, the cold rolling performed again after annealing causes work hardening, and thus although a thin and hard steel sheet can be manufactured, its formability is less than an R material.

- 15 **[0003]** As lids of beverage cans and food cans, easy open ends (EOEs) that can be opened easily are widely used. In manufacturing an EOE, it is necessary to form, by bulging, a rivet for attaching a tab with which a finger is engaged. Steel sheets as materials for manufacturing cans are required to have strengths according to sheet thicknesses, and as for the DR material, a tensile strength of not lower than about 520 MPa is necessary to ensure an economic effect due to thinning thereof. It is difficult to ensure for conventional DR materials both of formability and strength as mentioned above and thus the SR material has been used for EOEs. However, demands for applying the DR material to EOEs also are currently increasing in terms of cost reduction.

- 20 **[0004]** Due to such background, Patent Literature 1 discloses a steel sheet for easy open cans lids excellent in rivet formability, characterized in that its carbon content is not greater than 0.02% and its boron content is in a range of 0.010 to 0.020%, and a manufacturing method thereof, characterized in that second cold rolling is performed with a rolling reduction ratio of not greater than 30%. Moreover, Patent Literature 2 discloses a DR material characterized in that its average Lankford value after an aging treatment is not greater than 1.0, and describes that the DR material is excellent in EOE rivet formability.

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## Citation List

## Patent Literature

- 35 **[0005]**

Patent Literature 1: Japanese Patent No. 3740779

Patent Literature 2: WO 2008/018531

- 40 Summary

## Technical Problem

- 45 **[0006]** However, the conventional techniques described above have problems. As a diameter of a can lid to be applied becomes greater, a greater strength is required for a steel sheet, but since the steel sheet described in Patent Literature 1 has the small carbon content, the nitrogen content needs to be large to obtain a large strength. However, because the steel sheet contains at least a certain amount of boron, when the nitrogen content is large, its ductility at a high temperature becomes small and a slab crack is caused upon continuous casting. Therefore, the steel sheet described in Patent Literature 1 cannot be applied to an EOE having a large diameter.

- 50 **[0007]** The steel sheet described in Patent Literature 2 achieves the good rivet formability by reducing the average Lankford value. However, this method exerts its effects only when a rivet is formed by column-like bulging, and when a rivet is formed by sphere-like bulging, the rivet formability becomes insufficient. Therefore, provision of a high strength and high formability steel sheet having a tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm has been desired.

- 55 **[0008]** The present invention has been made in view of the above problems, and its object is to provide a high strength and high formability steel sheet and a manufacturing method thereof, which are able to provide a high strength and high formability steel sheet having a tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm.

## Solution to Problem

**[0009]** As a result of diligently performing intensive studies, the inventors of the present invention have found that it is effective, for achieving both formability and strength of a steel sheet, to ensure strength by increasing a nitrogen content while preventing deterioration of formability by restricting a carbon content to an appropriate range, and to restrict a second cold rolling reduction ratio after annealing to an appropriate range. Moreover, the inventors of the present invention have found that it is necessary to restrict also a coiling temperature to an appropriate range because, when the coiling temperature after hot rolling is high, precipitated cementite becomes coarse and local elongation deteriorates. Furthermore, the inventors of the present invention have found that rivet formability by bulging is remarkably improved by providing a resin film layer having an appropriate thickness on a side to be an inner surface of a can.

**[0010]** A high strength and high formability steel sheet according to the present invention includes, in mass%: greater than 0.020% and less than 0.040% of C; not less than 0.003% and not greater than 0.100% of Si; not less than 0.10% and not greater than 0.60% of Mn; not less than 0.001% and not greater than 0.100% of P; not less than 0.001% and not greater than 0.020% of S; not less than 0.005% and not greater than 0.100% of Al; greater than 0.0130% and not greater than 0.0170% of N; and a remainder being Fe and inevitable impurities, wherein the high strength and high formability steel sheet has: a resin film layer at least on a side to be an inner surface of a can; a tensile strength in a rolling direction of not less than 520 MPa; and an Erichsen value of not less than 5.0 mm.

**[0011]** A thickness of the resin film layer is preferably in a range of 5 to 100  $\mu\text{m}$ .

**[0012]** A method of manufacturing a high strength and high formability steel sheet according to the present invention includes: forming a slab by continuously casting a steel including, in mass%: greater than 0.020% and less than 0.040% of C; not less than 0.003% and not greater than 0.100% of Si; not less than 0.10% and not greater than 0.60% of Mn; not less than 0.001% and not greater than 0.100% of P; not less than 0.001% and not greater than 0.020% of S; not less than 0.005% and not greater than 0.100% of Al; greater than 0.0130% and not greater than 0.0170% of N; and a remainder being Fe and inevitable impurities; performing hot rolling at a slab reheating temperature of not lower than 1150°C; coiling at a temperature of not higher than 600°C; thereafter performing first cold rolling; thereafter performing continuous annealing at a soaking temperature of 600 to 700°C for a soaking period of 10 to 50 seconds; thereafter performing second cold rolling at a reduction ratio of 8.0 to 15.0%; attaching a resin film at least on a side to be an inner surface of a can after forming a surface treatment film by an electrolytic process; and manufacturing a steel sheet having a tensile strength in a rolling direction of not less than 520 MPa and an Erichsen value of not less than 5.0 mm.

## Advantageous Effects of Invention

**[0013]** According to the high strength and high formability steel sheet and the manufacturing method thereof of the present invention, it is possible to obtain a high strength and high formability steel sheet having a tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm. Further, as a result, it is possible to manufacture a lid with a DR material having a small thickness, without cracking upon EOE rivet formation, and thus to achieve thinning of a steel sheet for EOE's to a great extent.

## Description of Embodiments

**[0014]** In the following, the present invention is described in detail.

**[0015]** The high strength and high formability steel sheet of the present invention can be applied to a steel sheet for easy open ends having tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm. Such a steel sheet can be manufactured with steel having carbon content of less than 0.040%, by setting a coiling temperature after hot rolling and a second cold rolling reduction ratio to appropriate conditions, and attaching a resin film on a side to become an inner surface of a can. In the following, the component composition of the high strength and high formability steel sheet of the present invention is described.

## Component Composition of High Strength and High Formability Steel Sheet

(1) C: Greater than 0.020% and less than 0.040%

**[0016]** The high strength and high formability steel sheet of the present invention exerts high formability by suppressing carbon (C) content to small. When the C content is not less than 0.040%, a steel sheet becomes excessively hard, thus making it impossible to manufacture a thin steel sheet by second cold rolling while ensuring formability. Thus, the upper limit of C content is set to be less than 0.040%. However, when the C content is not greater than 0.020%, the tensile strength of 520 MPa that is required to obtain significant economic effects resulted by thinning of a steel sheet cannot be obtained. Thus, the lower limit of C content is set to exceed more than 0.020%.

(2) Si: Not less than 0.003% and not greater than 0.100%

**[0017]** When the silicon (Si) content exceeds 0.100%, there occur problems of deterioration of surface treatability, deterioration of corrosion resistance, etc. Thus, the upper limit of Si content is 0.100%. When Si content is set to be less than 0.003%, refining cost is excessively high. Therefore, the lower limit of Si content is set to be 0.003%. The preferable Si content is in a range of not less than 0.003% and not greater than 0.035%.

(3) Mn: Not less than 0.10% and not greater than 0.60%

**[0018]** Manganese (Mn) has functions of preventing red shortness during hot rolling due to sulfur (S) and of refining crystal grains, and is an element necessary for ensuring the desirable quality of a material. The addition of at least 0.10% or more of Mn is required in order to exert such effects. However, when an excessive amount of Mn is added, the corrosion resistance deteriorates and a steel sheet becomes excessively hard. The upper limit of Mn amount is therefore set to be 0.60%. The preferable Mn content is in a range of not less than 0.19% and not greater than 0.60%.

(4) P: Not less than 0.001% and not greater than 0.100%

**[0019]** Phosphorus (P) is a harmful element that hardens steel, and deteriorates formability, and in addition, deteriorates also corrosion resistance. Thus, the upper limit of P content is set to be 0.100%. However, when the P content is set to be less than 0.001%, the cost for dephosphorization becomes excessively high. The lower limit of P content is therefore set to be 0.001%. The preferable P content is in a range of not less than 0.001% and not greater than 0.015%.

(5) S: Not less than 0.001% and not greater than 0.020%

**[0020]** S exists as inclusions in steel, and is a harmful element causing deterioration of formability and deterioration of corrosion resistance. The upper limit of S content is therefore set to be 0.020%. When the S content is set to be less than 0.001%, the cost for desulfurization becomes excessively high. The lower limit of S content is therefore set to be 0.001%. The preferable P content is in a range of not less than 0.007% and not greater than 0.014%.

(6) Al: Not less than 0.005% and not greater than 0.100%

**[0021]** Aluminum (Al) is an element necessary as deoxidizer in a steelmaking process. When the Al content is small, deoxidation is insufficient, and inclusions increase, thus deteriorating formability. When the Al content is not less than 0.005%, it can be considered that deoxidation is performed sufficiently. However, when the Al content exceeds 0.100%, the frequency of occurrence of surface defects due to alumina clusters, etc. is increased. The Al content is therefore set to be not less than 0.005% and not greater than 0.100%.

(7) N: Greater than 0.0130% and not greater than 0.0170%

**[0022]** In the high strength and high formability steel sheet of the present invention, nitrogen (N) content is increased, instead of reducing C content, to ensure strength. The strengthening using N has small effects on bulging formability, and thus it is possible to strengthen a steel sheet without deteriorating an Erichsen value. When N content is not greater than 0.0130%, the strength necessary for a can lid cannot be obtained. However, when a large amount of N is added, the hot ductility deteriorates, thus causing a slab crack in continuous casting. The upper limit of N content is therefore set to be 0.0170%.

(8) Other components

**[0023]** The balance other than the components described above is iron (Fe) and inevitable impurities, and may include component elements normally contained in a known steel sheet for welded cans. For example, the component elements such as chromium (Cr): not greater than 0.10%, copper (Cu): not greater than 0.20%, nickel (Ni): not greater than 0.15%, molybdenum (Mo): not greater than 0.05%, titanium (Ti): not greater than 0.3%, niobium (Nb): not greater than 0.3%, zirconium (Zr): not greater than 0.3%, vanadium (V): not greater than 0.3%, calcium (Ca): not greater than 0.01%, may be contained depending on a purpose.

Characteristics of High Strength and High Formability Steel Sheet

**[0024]** Next, the mechanical characteristics of the high strength and high formability steel sheet of the present invention

are described.

**[0025]** The tensile strength of the high strength and high formability steel sheet of the present invention is set to be not lower than 520 MPa. When the tensile strength is lower than 520 MPa, a steel sheet cannot be made thin enough to obtain significant economic effects, in order to ensure the strength of the steel sheet as a material for manufacturing lids. The tensile strength is therefore set to be not lower than 520 MPa. The above tensile strength can be measured by Metallic materials-Tensile testing defined in the document "JIS Z 2241".

**[0026]** The Erichsen value of the high strength and high formability steel sheet of the present invention is set to be not less than 5.0 mm. When the Erichsen value is smaller than 5.0 mm, a crack occurs in rivet formation. The Erichsen value is therefore set to be not less than 5.0 mm. The Erichsen value can be measured by Method of Erichsen cupping test defined in the document "JIS Z 2247". In the rivet formation, the processing form applied on a steel sheet is bulging, which can be regarded as tensile deformation toward all directions parallel to a sheet surface. The evaluation of deformability of a steel sheet by such processing requires a test by similar bulging, and the deformability cannot be evaluated with a total elongation value or a Lankford value by the simple uniaxial tensile testing.

#### Surface Coating of High Strength and High Formability Steel Sheet

**[0027]** Next, the surface coating of the high strength and high formability steel sheet of the present invention is described.

**[0028]** The rivet formation is performed by bulging, and processing for bulging toward the outer side of a can is performed. In the processing, therefore, a steel sheet is deformed by a tool contacting with the inner side surface of the can. The lubricating ability between a tool and a steel sheet is improved by contacting them with a resin film interposed therebetween. Thus, the uniformity of bulging is improved, suppressing the occurrence of a crack effectively. It is more preferable that a surface of a steel sheet be coated with a resin film in addition to interposing a resin film between a tool and a steel sheet, because those contribute to corrosion resistance.

**[0029]** A resin film is not particularly limited, and various thermoplastic resins and thermosetting resins can be used. For example, there may be used an olefin resin film such as of polyethylene, polypropylene, ethylenepropylene copolymer, ethylene-vinyl acetate copolymer, ethylene-acrylic ester copolymer, and ionomer, or a polyester film such as of polybutylene terephthalate, or a thermoplastic resin film including a polyamide film such as of nylon 6, nylon 6-6, nylon 11, and nylon 12, a polyvinylchloride film, and a polyvinylidene chloride film without stretching them or by stretching them biaxially.

**[0030]** When an adhesive is used to attach a resin film on a steel sheet, an urethane adhesive, an epoxy adhesive, an acid-modified olefin resin adhesive, a copolyamide adhesive, a copolyester adhesive (thickness: 0.1 to 5.0  $\mu\text{m}$ ), etc. are used preferably. Moreover, thermosetting coating is applied on the steel sheet side or the resin film side with a thickness in a range of 0.05 to 2.0  $\mu\text{m}$ , and this may be regarded as an adhesive. Moreover, thermoplastic or thermosetting coating including modified epoxy coating such as of phenol epoxy and amino-epoxy, vinyl chloride-vinyl acetate copolymer, vinyl chloride acetate saponified copolymer, vinyl chloride-vinyl acetate-maleic anhydride copolymer, epoxy modified-, epoxy amino modified-, epoxy phenol modified-vinyl coating or modified vinyl coating, acrylic coating, and a synthetic rubber coating such as of styrene-butadiene copolymer may be used individually or in combination of two or more thereof.

**[0031]** The thickness of a resin film is preferably set to be in a range of 5 to 100  $\mu\text{m}$ . When the thickness of a resin film is smaller than 5  $\mu\text{m}$ , the resin film is fractured in bulging, and it is more possible that the effects are not exerted sufficiently. When the thickness of a resin film exceeds 100  $\mu\text{m}$ , the effect of increasing a deformation amount of a steel sheet becomes greater, and a crack of the steel sheet will occur more easily.

#### Manufacturing Method of High Strength and High Formability Steel Sheet

**[0032]** Next, the manufacturing method of the high strength and high formability steel sheet of the present invention is described.

**[0033]** The high strength and high formability steel sheet of the present invention is manufactured, with use of a steel slab having the above composition manufactured by continuous casting, by performing hot rolling at a slab reheating temperature of not lower than 1150°C, coiling it at a temperature of not higher than 600°C, performing first cold rolling, performing continuous annealing at a soaking temperature of 600 to 700°C for a soaking period of 10 to 50 seconds, performing second cold rolling with a reduction ratio of 8.0 to 15.0%, forming a surface treatment film by an electrolytic process, and then attaching a resin film at least on a side to become an inner surface of a can.

**[0034]** It is normally difficult, with only one-time cold rolling, to make a sheet thin enough to obtain significant economic effects. That is, in order to obtain a thin sheet with one-time cold rolling, the load on a mill becomes too high, and it is impossible to achieve it depending on a plant capacity. For example, when a final sheet thickness is made 0.15 mm, the first cold reduction ratio of as much as 92.5% is required if a sheet thickness after hot rolling is 2.0 mm. It can be also considered that a sheet is rolled to be thinner than usual at the step of hot rolling to reduce a sheet thickness after cold rolling. However, when the reduction ratio in hot rolling is increased, the reduction of a temperature of a steel sheet

during rolling becomes great, and a given finish rolling temperature cannot be obtained. Moreover, when continuous annealing is performed, the possibility of the occurrence of troubles such as fracture or deformation of a steel sheet during annealing becomes higher if a sheet thickness before annealing is set to be small. For these reasons, it is preferable in the present invention that the cold rolling for the second time (second cold rolling) be performed after annealing to obtain an ultrathin steel sheet.

**[0035]** When a coiling temperature after hot rolling exceeds 600°C, a pearlite structure to be formed becomes coarse, which is a starting point of brittle fracture and thus reduces local elongation, making it difficult to obtain an Erichsen value of not less than 5.0 mm. The coiling temperature after hot rolling is therefore preferably not higher than 600°C, and is more preferably in a range of 550 to 600°C.

**[0036]** When the soaking temperature of continuous annealing is lower than 600°C or the soaking period thereof is shorter than 10 seconds, recrystallization is insufficient, thus making it difficult to obtain an Erichsen value of not less than 5.0 mm. However, when the soaking temperature exceeds 700°C or the soaking period exceeds 50 seconds, the grain growth through recrystallization becomes excessive, thus making it difficult to obtain the tensile strength of 520 MPa. The continuous annealing is therefore preferably performed under conditions of a soaking temperature of 600 to 700°C and a soaking period of 10 to 50 seconds.

**[0037]** When the second cold rolling reduction ratio exceeds 15.0%, work hardening by the second cold rolling becomes excessive, thus making it difficult to obtain an Erichsen value of not less than 5.0 mm. The second cold rolling reduction ratio is therefore preferably not greater than 15.0%. However, when the second cold rolling reduction ratio is less than 8.0%, it is difficult to obtain strength necessary for a can lid. Thus, the lower limit of the second cold rolling reduction ratio is preferably 8.0%.

**[0038]** After the second cold rolling, a surface treatment film is formed by an electrolytic process. As a film, a Sn electroplating film, an electrolytic Cr acid treatment film, or the like, which is widely used for a can lid as a tin plate or tin-free steel, can be applied. The adherence between a resin film and a steel sheet can be improved by providing such a film.

**[0039]** After the surface treatment film is formed, a resin film is attached at least on a side to become an inner surface of a can. The attachment method can be a method of heating a steel sheet and heat-sealing a resin film, or a method of attaching it using an adhesive.

#### Examples

**[0040]** A steel slab was obtained by melting steel having the component compositions illustrated in Table 1 and the balance including Fe and inevitable impurities in an actual converter and subjecting it to continuous casting. The obtained steel slab was heated again, and subjected to hot rolling under the conditions illustrated in Table 2. A finish rolling temperature of hot rolling was set to be 880°C, and pickling was performed after the rolling. Next, after first cold rolling was performed with a reduction ratio of 90%, continuous annealing and second cold rolling were performed under the conditions illustrated in Table 2. The electrolytic Cr acid treatment was continuously performed on the both surfaces of the steel sheet obtained in the above manner, whereby tin-free steel having a Cr coating build-up per side of 100 mg/m<sup>2</sup> was obtained. Then, an isophthalic acid copolymerized polyethylene terephthalate film having a copolymerization ratio of 12 mol% was laminated on the both surfaces, and thus a resin coated steel sheet was obtained. The laminating was performed in such a manner that a steel sheet heated to 245°C and a film were nipped by a pair of rubber covered rolls so that the film was fused to the metallic sheet, and the laminate was cooled with water within one second after it passed the rubber covered rolls. Here, a feed rate of the steel sheet was 40 m/min, and the nip length of the rubber covered rolls was 17 mm. The nip length is a length in a feed direction of a part where the rubber covered rolls and the steel sheet are in contact. The thickness of film layers was listed in Table 1.

Table 1

| No. | Component composition (mass%) |       |      |       |       |       |        | Thickness of resin film layer (μm) |
|-----|-------------------------------|-------|------|-------|-------|-------|--------|------------------------------------|
|     | C                             | Si    | Mn   | P     | S     | Al    | N      |                                    |
| 1   | 0.031                         | 0.011 | 0.29 | 0.009 | 0.010 | 0.039 | 0.0153 | 18                                 |
| 2   | 0.021                         | 0.010 | 0.23 | 0.010 | 0.012 | 0.018 | 0.0161 | 24                                 |
| 3   | 0.039                         | 0.012 | 0.25 | 0.009 | 0.010 | 0.025 | 0.0140 | 15                                 |
| 4   | 0.026                         | 0.008 | 0.28 | 0.012 | 0.008 | 0.042 | 0.0170 | 5                                  |
| 5   | 0.035                         | 0.009 | 0.30 | 0.013 | 0.011 | 0.048 | 0.0131 | 51                                 |
| 6   | 0.029                         | 0.010 | 0.19 | 0.010 | 0.012 | 0.041 | 0.0148 | 100                                |

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(continued)

| No.                                                                                                                     | Component composition (mass%) |       |      |       |       |       |        | Thickness of resin film layer (μm) |
|-------------------------------------------------------------------------------------------------------------------------|-------------------------------|-------|------|-------|-------|-------|--------|------------------------------------|
|                                                                                                                         | C                             | Si    | Mn   | P     | S     | Al    | N      |                                    |
| 7                                                                                                                       | 0.020                         | 0.011 | 0.26 | 0.011 | 0.009 | 0.040 | 0.0152 | 30                                 |
| 8                                                                                                                       | 0.040                         | 0.013 | 0.25 | 0.010 | 0.010 | 0.051 | 0.0160 | 29                                 |
| 9                                                                                                                       | 0.032                         | 0.012 | 0.27 | 0.009 | 0.011 | 0.044 | 0.0130 | 19                                 |
| 10                                                                                                                      | 0.028                         | 0.010 | 0.22 | 0.012 | 0.010 | 0.038 | 0.0175 | -                                  |
| 11                                                                                                                      | 0.035                         | 0.014 | 0.27 | 0.010 | 0.009 | 0.033 | 0.0162 | 20                                 |
| 12                                                                                                                      | 0.029                         | 0.011 | 0.25 | 0.011 | 0.012 | 0.054 | 0.0159 | 36                                 |
| 13                                                                                                                      | 0.030                         | 0.009 | 0.24 | 0.013 | 0.014 | 0.064 | 0.0141 | 14                                 |
| 14                                                                                                                      | 0.031                         | 0.008 | 0.21 | 0.010 | 0.010 | 0.050 | 0.0135 | 27                                 |
| 15                                                                                                                      | 0.022                         | 0.010 | 0.30 | 0.012 | 0.011 | 0.042 | 0.0155 | 43                                 |
| 16                                                                                                                      | 0.026                         | 0.012 | 0.28 | 0.008 | 0.012 | 0.040 | 0.0152 | 26                                 |
| 17                                                                                                                      | 0.033                         | 0.011 | 0.25 | 0.010 | 0.009 | 0.034 | 0.0143 | 39                                 |
| 18                                                                                                                      | 0.037                         | 0.010 | 0.31 | 0.011 | 0.010 | 0.032 | 0.0148 | 3                                  |
| 19                                                                                                                      | 0.034                         | 0.013 | 0.24 | 0.009 | 0.013 | 0.041 | 0.0151 | 112                                |
| *Due to occurrence of slab crack in steel sheet No. 10 in continuous casting, operations thereafter were not performed. |                               |       |      |       |       |       |        |                                    |

Table 2

| No. | Hot rolling coiling temperature (°C) | Continuous annealing soaking temperature (°C) | Continuous annealing soaking period (second) | Second cold rolling reduction ratio (%) |
|-----|--------------------------------------|-----------------------------------------------|----------------------------------------------|-----------------------------------------|
| 1   | 582                                  | 668                                           | 21                                           | 11.5                                    |
| 2   | 589                                  | 685                                           | 21                                           | 9.8                                     |
| 3   | 575                                  | 698                                           | 10                                           | 8.3                                     |
| 4   | 598                                  | 621                                           | 23                                           | 10.6                                    |
| 5   | 552                                  | 605                                           | 49                                           | 14.9                                    |
| 6   | 563                                  | 654                                           | 22                                           | 12.7                                    |
| 7   | 584                                  | 620                                           | 23                                           | 13.1                                    |
| 8   | 571                                  | 683                                           | 21                                           | 11.1                                    |
| 9   | 591                                  | 667                                           | 21                                           | 10.9                                    |
| 10  | -                                    | -                                             | -                                            | -                                       |
| 11  | 604                                  | 644                                           | 22                                           | 9.2                                     |
| 12  | 585                                  | 598                                           | 24                                           | 12.2                                    |
| 13  | 587                                  | 703                                           | 15                                           | 14.0                                    |
| 14  | 592                                  | 683                                           | 9                                            | 12.5                                    |
| 15  | 566                                  | 672                                           | 52                                           | 10.3                                    |
| 16  | 570                                  | 658                                           | 22                                           | 7.8                                     |
| 17  | 581                                  | 631                                           | 23                                           | 15.5                                    |
| 18  | 590                                  | 689                                           | 21                                           | 13.3                                    |

(continued)

| No.                                                                                                                     | Hot rolling coiling temperature (°C) | Continuous annealing soaking temperature (°C) | Continuous annealing soaking period (second) | Second cold rolling reduction ratio (%) |
|-------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------------------------------|----------------------------------------------|-----------------------------------------|
| 19                                                                                                                      | 588                                  | 690                                           | 21                                           | 10.1                                    |
| *Due to occurrence of slab crack in steel sheet No. 10 in continuous casting, operations thereafter were not performed. |                                      |                                               |                                              |                                         |

**[0041]** The resin coated steel sheet obtained as described above was subjected to tensile testing. The tensile testing conforms to Metallic materials-Tensile testing defined in the document "JIS Z 2241", and strength of tension (tensile strength) was measured using a test piece for tensile testing having a size of JIS5. Moreover, the obtained resin coated steel sheet was subjected to Erichsen test. The Erichsen test conforms to Method of Erichsen cupping test defined in the document "JIS Z 2247", and an Erichsen value (a bulging height at which a penetration crack occurred) was measured using a test piece of 90 mm x 90 mm. Furthermore, a rivet for attaching an EOE tab was formed using the obtained resin coated steel sheet, and the rivet formability was evaluated. The rivet formation was performed by three phases of press working, and processing for reducing a diameter was performed after bulging to form a spherical-head-formed rivet having a diameter of 4.0 mm and a height of 2.5 mm. Occurrence of a crack in a rivet portion was evaluated as "C", occurrence of necking in a thickness direction, which is a previous stage leading to a crack, was evaluated as "B", and no occurrence of a crack or necking in a thickness direction was evaluated as "A". The obtained results are listed in Table 3.

Table 3

| No.                                                                                                                     | Tensile strength (MPa) | Erichsen value (mm) | Rivet formability |                                                                     |
|-------------------------------------------------------------------------------------------------------------------------|------------------------|---------------------|-------------------|---------------------------------------------------------------------|
| 1                                                                                                                       | 552                    | 6.9                 | A                 | Inventive Example                                                   |
| 2                                                                                                                       | 535                    | 7.4                 | A                 | Inventive Example                                                   |
| 3                                                                                                                       | 523                    | 7.6                 | A                 | Inventive Example                                                   |
| 4                                                                                                                       | 539                    | 7.0                 | A                 | Inventive Example                                                   |
| 5                                                                                                                       | 591                    | 5.2                 | A                 | Inventive Example                                                   |
| 6                                                                                                                       | 557                    | 6.5                 | A                 | Inventive Example                                                   |
| 7                                                                                                                       | 516                    | 6.2                 | A                 | Comparative Example                                                 |
| 8                                                                                                                       | 592                    | 4.8                 | C                 | Comparative Example                                                 |
| 9                                                                                                                       | 517                    | 7.3                 | A                 | Comparative Example                                                 |
| 10                                                                                                                      | -                      | -                   | -                 | Comparative Example                                                 |
| 11                                                                                                                      | 532                    | 4.2                 | C                 | Comparative Example                                                 |
| 12                                                                                                                      | 595                    | 4.8                 | C                 | Comparative Example                                                 |
| 13                                                                                                                      | 512                    | 6.1                 | A                 | Comparative Example                                                 |
| 14                                                                                                                      | 603                    | 4.9                 | C                 | Comparative Example                                                 |
| 15                                                                                                                      | 515                    | 7.2                 | A                 | Comparative Example                                                 |
| 16                                                                                                                      | 517                    | 7.9                 | A                 | Comparative Example                                                 |
| 17                                                                                                                      | 599                    | 4.9                 | C                 | Comparative Example                                                 |
| 18                                                                                                                      | 564                    | 6.0                 | B                 | Inventive Examples of Claims 1 and 3 Comparative Example of Claim 2 |
| 19                                                                                                                      | 538                    | 7.3                 | B                 | Inventive Examples of Claims 1 and 3 Comparative Example of Claim 2 |
| *Due to occurrence of slab crack in steel sheet No. 10 in continuous casting, operations thereafter were not performed. |                        |                     |                   |                                                                     |

**[0042]** As listed in Table 3, the steel sheets of Inventive Examples No. 1 to No. 6 are excellent in strength, and achieve tensile strength of not lower than 520 MPa that is required as an ultrathin steel sheet for cans. Moreover, they are also



excellent in formability, and have an Erichsen value of not less than 5.0 mm that is required in EOE processing. Furthermore, even if the rivet formation is performed, no crack or necking in a thickness direction occurs. By contrast, each of the steel sheets of Comparative Examples No. 7 and No. 9 has such small C and N content that they are lacking in tensile strength. The steel sheet of Comparative Example No. 8 has such large C content that the formability is deteriorated by second cold rolling, resulting in the lack in Erichsen value and thus causing a crack in rivet formation.

**[0043]** The steel sheet of Comparative Example No. 10 has such large N content that a slab crack has occurred in continuous casting. Regarding the steel sheet of Comparative Example No. 11, the local elongation deteriorates because the coiling temperature after hot rolling is too high, resulting in the lack in Erichsen value and thus causing a crack in rivet formation. Regarding the steel sheet of Comparative Example No. 12, recrystallization is insufficient because the soaking temperature in continuous annealing is too low, resulting in the lack in Erichsen value and thus causing a crack in rivet formation. Regarding the steel sheet of Comparative Example No. 13, grain growth is excessive because the soaking temperature in continuous annealing is too high, resulting in the lack in tensile strength. Regarding the steel sheet of Comparative Example No. 14, recrystallization is insufficient because the soaking period in continuous annealing is too short, resulting in the lack in Erichsen value and thus causing a crack in rivet formation.

**[0044]** Regarding the steel sheet of Comparative Example No. 15, grain growth is excessive because the soaking period in continuous annealing is too long, resulting in the lack in tensile strength. The steel sheet of Comparative Example No. 16 is lacking in tensile strength because the second cold rolling reduction ratio is too small. Regarding the steel sheet of Comparative Example No. 17, work hardening becomes excessive because the second cold rolling reduction ratio is too high, resulting in the lack in Erichsen value and thus causing a crack in rivet formation. Regarding the steel sheet of No. 18 that is Inventive Example of claims 1 and 3 and is Comparative Example of claim 2, the thickness of the resin film coating the surface of the steel sheet is too thin, and thus the effects thereof are not sufficiently exerted in rivet formation, causing a necking crack in a thickness direction before leading to a crack. Regarding the steel sheet of No. 19 that is Inventive Example of claims 1 and 3 and is Comparative Example of claim 2, the thickness of the resin film coating the surface of the steel sheet is too thick, and thus the deformation amount of the steel sheet is increased in rivet formation, causing a necking crack in a thickness direction before leading to a crack.

**[0045]** Based on the above, it was confirmed that according to the steel sheets of the inventive examples, it is possible to obtain a high strength and high formability steel sheet having tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm.

**[0046]** The embodiments to which the present invention made by the inventors are applied have been described. However, the present invention is not limited by the description and the drawings that form a part of the disclosure of the present invention in the embodiments. That is, other embodiments, examples, and operation technologies that are made based on the present embodiments by a person skilled in the art, etc. are all included in the scope of the present invention.

#### Industrial Applicability

**[0047]** According to the present invention, it is possible to provide a high strength and high formability steel sheet having tensile strength of not lower than 520 MPa and an Erichsen value of not less than 5.0 mm.

#### Claims

1. A high strength and high formability steel sheet, comprising, in mass%:

greater than 0.020% and less than 0.040% of C;  
not less than 0.003% and not greater than 0.100% of Si;  
not less than 0.10% and not greater than 0.60% of Mn;  
not less than 0.001% and not greater than 0.100% of P;  
not less than 0.001% and not greater than 0.020% of S;  
not less than 0.005% and not greater than 0.100% of Al;  
greater than 0.0130% and not greater than 0.0170% of N; and  
a remainder being Fe and inevitable impurities,  
wherein  
the high strength and high formability steel sheet has:

a resin film layer at least on a side to be an inner surface of a can;  
a tensile strength in a rolling direction of not less than 520 MPa; and  
an Erichsen value of not less than 5.0 mm.

2. The high strength and high formability steel sheet according to claim 1, wherein a thickness of the resin film layer is in a range of 5 to 100  $\mu\text{m}$ .

3. A method of manufacturing a high strength and high formability steel sheet, the method comprising:

forming a slab by continuously casting a steel including:

greater than 0.020% and less than 0.040% of C;  
not less than 0.003% and not greater than 0.100% of Si;  
not less than 0.10% and not greater than 0.60% of Mn;  
not less than 0.001% and not greater than 0.100% of P;  
not less than 0.001% and not greater than 0.020% of S;  
not less than 0.005% and not greater than 0.100% of Al;  
greater than 0.0130% and not greater than 0.0170% of N; and  
a remainder being Fe and inevitable impurities;

performing hot rolling at a slab reheating temperature of not lower than 1150°C;

coiling at a temperature of not higher than 600°C;

thereafter performing first cold rolling;

thereafter performing continuous annealing at a soaking temperature of 600 to 700°C for a soaking period of 10 to 50 seconds;

thereafter performing second cold rolling at a reduction ratio of 8.0 to 15.0%;

attaching a resin film at least on a side to be an inner surface of a can after forming a surface treatment film by an electrolytic process; and

manufacturing a steel sheet having a tensile strength in a rolling direction of not less than 520 MPa and an Erichsen value of not less than 5.0 mm.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/060175

## A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, B21B3/00(2006.01)i, C21D9/46(2006.01)i, C22C38/06  
(2006.01)i, C25D5/26(2006.01)i, C22C38/50(2006.01)n

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, B21B3/00, C21D9/46, C22C38/06, C25D5/26, C22C38/50

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 1996-2013  
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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         | WO 2009/123356 A1 (JFE Steel Corp.),<br>08 October 2009 (08.10.2009),<br>claims; description, page 5, line 6 to page 10,<br>line 9; tables 1 to 2<br>& JP 2009-263788 A & US 2011/0076177 A1<br>& CN 101983251 A & KR 10-2010-0119821 A<br>& TW 200948985 A1 | 1-3                   |
| A         | WO 2008/018531 A1 (Nippon Steel Corp.),<br>14 February 2008 (14.02.2008),<br>claims; paragraphs [0029] to [0030]; tables 1<br>to 2<br>& US 2009/0250147 A1 & EP 2050834 A1<br>& CN 101454470 A & KR 10-2009-0007796 A<br>& TW 200827460 A                    | 1-3                   |

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

☐ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search  
26 June, 2013 (26.06.13)

Date of mailing of the international search report  
09 July, 2013 (09.07.13)

Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/060175

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                              | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | JP 2004-218061 A (Nippon Steel Corp.),<br>05 August 2004 (05.08.2004),<br>claims; paragraphs [0046], [0052]; tables 1 to<br>2<br>(Family: none) | 1-3                   |
| A         | JP 5-33188 A (Nippon Steel Corp.),<br>09 February 1993 (09.02.1993),<br>paragraphs [0005], [0011]<br>(Family: none)                             | 1-3                   |

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 3740779 B [0005]
- WO 2008018531 A [0005]