DESCRIPTION

STAINLESS STEEL SHEET FOR PARTS AND PRODUCTION METHOD THEREOF

Technical Field

[0001] The present invention relates to a stainless steel sheet processed to be industrial products and the production method thereof. More specifically, the present invention relates to a stainless steel sheet for parts which exhibits high-strength, high-fatigue property, and excellent workability together with high-flatness and low-residual stress and also relates to the production method thereof. In other words, the invention relates to a stainless steel sheet which exhibits excellent performance in many products or parts produced from the stainless steel sheet or the steel strip (hereinafter, collectively, refer to as "stainless steel sheet".) and relates to the production method thereof. Particularly, the invention relates to a stainless steel sheet suitably used for a wide variety of parts which requires higher precision and complexity with miniaturization and weight saving of the products and which are embedded in the industrial products and relates to the production method thereof.

Background Art

[0002] Inside and outside of various industrial products such as automobile, home electric appliances, IT equipment, and cellular telephone, a wide variety of parts are used. Materials of these parts are also diverse, metal material is in heavy usage;

among them, stainless steel is particularly used. The majority of parts made of stainless steel are produced from stainless steel sheets by methods like press working or etching.

[0003] For example, in case of press working, a stainless steel sheet is firstly worked into a piece of predetermined dimensions by cutting, blanking, and so on; then, the obtained piece is formed into a certain shape by using dies. One of the typical examples thereof may be springs. Spring is used in many industrial products and it may often be used in many sites of one product. Spring has a wide variety and it can be roughly classified into disc spring and leaf spring, in view of shape. Specific examples thereof include: a washer inserted between a bolt and a nut; small-sized disc spring used underneath buttons of cellular telephone; gasket and metal packing respectively used for automobiles and motorcycles.

[0004] On the other hand, etching is carried out by forming a pattern on the sheet surface by using photoresist technique, dipping the patterned sheet into an acid. Then, by using chemical means in a manner like spraying, a part of the material is made corroded and the corroded part is removed (etched) to obtain a shape corresponding to the pattern. Etching is often used in a case where press working is difficult, for instance, working for precision parts. The examples of the parts may be gimbals (spring) used for fixing magnetic head, small-sized parts like gears for feeding printer paper, shadow masks of conventional TV which requires to have an extremely large number of minute holes, and mesh for printing printed-circuit board.

[0005] In recent years, since miniaturization and weight

saving have been developed and further complexity and higher-precision are required for parts, the following properties are further required of parts using such a stainless steel.

(Strength) Parts like spring are given stress and many of other parts have structural aspect so that the material should have high-strength against decrease of stiffness by miniaturization and weight saving.

(Formability) With the trend of further complexity and higher-precision of parts, in order to process parts having more complex shape to become highly precise, excellent formability is required. In general, formability is in proportion to the elongation (ductility) of the material; although a relation of strength and elongation is incompatible, compatibility between higher-strength and excellent formability is required.

(Etchability) Similar to the above, with the trend of further complexity and higher-precision of parts, in order to obtain a flat and smooth worked surface without having defects such as locally caused holes (etch pit), excellent etchability is required.

(Fatigue property) To springs, varying stress is often loaded repeatedly and the deformation volume is varied with miniaturization and weight saving of the parts. Therefore, excellent fatigue property is required. Moreover, there are cases where finished parts are quite often excellent in material stage but largely deteriorated by the following forming, thereby those parts are required to become excellent as finished products and to have high reliability.

(Flatness) In order to stably obtain a shape of parts

continuously seeking higher-precision and further complexity and to lower fraction defective (i.e. to increase the yield.) at a time of assembly to the product achieving miniaturization and weight saving, excellent sheet shape and high flatness are required.

(Residual stress) In case where the parts are taken from the relatively larger material (to the parts), the parts are released from the surrounding restriction and the shapes thereof are changed due to the release of residual stress. Namely, the parts do not show a predetermined shape, but fraction defective is raised (yield is decreased) at a time of assembly to the product achieving miniaturization and weight saving. So, the parts are required to have stability and low-residual stress.

[0006] Conventionally, to the parts as described above, metastable austenitic (γ) stainless steel such as SUS 301 and SUS 304 has been used. By working the austenitic stainless steel at room temperature, transformation (stress-induced martensitic (α') transformation) from γ-parent phase to solid martensitic phase can be caused. As a result, it is possible to obtain a stainless steel sheet having a certain extent of ductility and higher strength. The working is normally carried out by cold rolling so that the strength can be adjusted by adjusting rolling reduction of the cold rolling. The reason that high-strength can be obtained without loosing ductility is because the rolled portion only becomes hardened by stress-induced martensitic (α') transformation so that local deformation is inhibited and deformation is transferred to a soft untransformed portion (γ-part) to evenly deform the entire material, whereby shows high

elongation. This is the so-called "Transformation-Induced Plasticity (TRIP) effect". According to the above characteristics, metastable austenitic (γ) stainless steel is also classified in Japanese Industrial Standard (JIS G4313) as a stainless steel for the use of spring.

[0007] With respect to fatigue property of these stainless steels, Patent document 1 discloses an invention where dimensions of compounds to be a source of breakage are restricted. Moreover, with respect to etchability, Patent document 2 discloses an invention where distribution of compounds to be a source of etch pit (hole) is restricted. Further, Patent document 3 discloses formability by microfabrication of crystal grain and improvement of fatigue property.

[0008] Production steps of these metastable austenitic (γ) stainless steels can be described by the process having the steps roughly shown in Fig. 5. As it were, after molten ingot is hot-rolled and annealed as required, as shown in Fig. 5, cold rolling and annealing are repeated to reduce the thickness of the sheet to obtain a predetermined thickness. Following to it, temper rolling, leveling, and straightening annealing are carried out. Among them, by temper rolling, thickness of the product sheet is reduced and adjustment of mechanical properties can be done with work hardening, simultaneously. So as to obtain targeted mechanical properties with thickness of the product sheet upon completion of temper rolling, thickness of the sheet has been reduced to the predetermined thickness. Thereafter, within the range which does not largely change the mechanical properties, improvement of flatness by leveling and reduction

of residual stress by straightening annealing are carried out.

[0009] Further, for improving a series of the above production processes, Patent documents 4 and 5 disclose TA (Tension-Annealing) treatment. The treatment is the one in which tension is imparted without largely changing the post-temper-rolling mechanical properties and the tensile material is heated at relatively lower temperature. By these inventions, improvement of flatness and reduction of residual stress can be done at the same time.

[0010] Still further, as one of other production methods, Patent documents 6 and 7 disclose production methods of stainless steel including temper-annealing method and a high-performance metastable γ-stainless steel sheet which can be obtained by the temper-annealing method. The schematic flow of the process is shown in Fig. 6. This is a method about treatment of stainless steel material having the predetermined composition, in which the material hardened by cold rolling for reducing the sheet thickness to the finished thickness is softened by temper-annealing and the performance is adjusted. Accordingly, the material gets to have a mixed structure of recrystallized grain and unrecrystallized portion remaining influence of the previous working; hence, by adjusting the optimal ratio, high-strength and high-ductility can be made compatible. Still further, at a time of temper-annealing, transformation (refer to as "reverse transformation".) from stress-induced martensitic (α') phase to austenitic (γ) parent phase, recovery, and recrystallization are caused, that results in the reduction of residual stress. In addition, since reverse transformation is

developed with volume change, it is possible to adjust softening by imparting tension; adjustment of mechanical properties and leveling can also be relatively easily done in short period of time. In other words, high-performance material which is suitable for the material of parts assembled inside the product can be reasonably and stably produced.

[0011] Still further, Patent documents 8 to 10 disclose a stainless steel sheet for photo-etching by specifying rolling condition and heat treatment condition of the stainless steel sheet as a material and by increasing etching speed within crystal grain by introducing transformation and martensite into crystal grain. By making the etching speed within the area of the crystal grain equivalent to the etching speed in the grain boundary, and so on, flatness of the etched surface is improved.

[0012]

Patent Document 1: Japanese Patent Application Laid-Open No. 2005-290449

Patent Document 2: Japanese Patent Application Laid-Open No. 2000-273586

Patent Document 3: Japanese Patent Application Laid-Open No. 5-279802

Patent Document 4: Japanese Patent Application Laid-Open No. 10-34237

Patent Document 5: Japanese Patent Application Laid-Open No. 2001-226718

Patent Document 6: Japanese Patent No. 3603726

Patent Document 7: Japanese Patent Application Laid-Open No. 2002-194506

Patent Document 8: Japanese Patent Application Laid-Open No. 2005-314772

Patent Document 9: Japanese Patent Application Laid-Open No. 2005-320586

Patent Document 10: Japanese Patent Application Laid-Open No. 2005-320587

Disclosure of the Invention

Problems to be solved by the Invention

[0013] However, a stainless steel sheet has been required for responding to recent tendency of miniaturization, weight saving, and high-precision about parts, further improvement in terms of the above properties has been required. Each invention respectively shown in Patent documents 1 to 3 has a limit so that further improvement is required. Particularly about spring, there are problems in improvement of fatigue property after finishing and improvement of workability (formability and etchability) being able to accurately work miniaturized parts.

[0014] The production method also have similar problems, so there is an issue to adopt a method for producing the stainless steel sheet which is capable of solving the above problems. Nevertheless, by the conventional production method or production methods of Patent documents 4 and 5, compatibility between high-strength and high-ductility of the material is limited. In addition, since the materials are required to be thinner and stronger, leveling becomes difficult so that the sheet shape tends to be deteriorated. Moreover, straightening annealing takes a long time, this results in a factor for interfering productivity.

Further, as there are a wide variety of parts having different thickness and hardness of the sheet as well as amount used (sometimes relatively small), the variation causes a remarkable problem that lead to a substantial increase of product cost.

[0015] In the production methods of Patent documents 6 and 7, there are issues in promotion of miniaturization and weight saving of the products and parts as well as further improvement of workability to correspond to the wide variety of products.

[0016] By the stainless steel sheets for photo-etching described of Patent documents 8 to 10, smoothness in etched surface can be obtained; however, these do not necessarily show favorable strength, ductility, and fatigue property. Thus, further improvement has been required.

[0017] Accordingly, an object of the present invention is to provide a stainless steel sheet which exhibits favorable strength and ductility and which is capable of improving workability (formability, etchability) and fatigue property. Another object of the invention is to provide a method for producing the stainless steel sheet. Further, by the method for producing the stainless steel sheet, the invention is aimed at industrially and stably providing the stainless steel sheet of the invention with inexpensive price.

Means for Solving the Problems

[0018] The present inventors had seriously studied the above problems. As a result, the inventors discovered the following findings to solve the above problems and the present invention was completed. In other words, the inventors studied to obtain

a mixed structure (mixed structure of highly-ductile recrystallized structure and unrecrystallized structure in which high-strength stress-induced martensitic phase remains) for improving the properties of stainless steel sheet which cannot be obtained from the conventional stainless steel sheet and the production method. In order to attain this, final rolling rate in thickness in a series of rolling process and influence of material composition were seriously studied. Consequently, stainless steel sheet having the below-described mixed structure can be obtained; by the production method, it also becomes apparent that workability, fatigue property, and so on can be improved.

[0019] The above discovery is based on the following findings.

(a) The mechanical properties of the stainless steel are improved by a structure having the mixed structure. Namely, recrystallized portion in the mixed structure gives effects for strengthening by microfabrication of crystal grain and for inhibiting uneven deformation by density rise along grain boundary. On the other hand, about the unrecrystallized portion in the mixed structure, TRIP effect can be obtained by work hardening and stress-induced α'-transformation from γ-phase being reversely transformed. Hence, the materials can maintain high-strength from the combination effects. In addition, deformation is developed evenly so that formability (ductility) is improved. In the similar manner, etchability is understood that etched surface becomes even by grain refining and increase of γ-parent phase as a unitary construction. As a result, uneven

portion to be a source of fatigue breakdown disappears and fatigue property after formation and after etching is improved.

[0020] (b) By optimizing various conditions of material compositions and adjusting distribution of mixed structure and indwelled compounds of the stainless steel sheet, it is possible to improve workability and fatigue property of the materials. Specifically, in addition to the mixed structure, by setting the number of indwelled compounds whose maximum diameter is 20 μm or more to 30 or less per 5g (mass), defects which becomes obvious by working cannot be observed, whereby worked surface becomes smooth. Due to this, 90% or more of fatigue strength to that of before working can be maintained. Since fatigue breakdown is occurred by the concentration of stress to the defects, improvement of the fatigue strength is thought to be achieved by decreasing the defects.

[0021] (c) As for the production method, during the production, tension given to the stainless steel sheet changes the ratio of recrystallized grain including γ-phase in the structure of the stainless steel sheet or the ratio of γ-phase in the unrecrystallized portion. This happens because when the production method having temper-annealing is adopted, reverse transformation, with volume change, from α'-(stress-induced martensitic) phase to γ-parent phase is restricted by the tension at the time of temper-annealing. As given tension makes the material softer, it is understood that increase of tension inhibits reverse transformation and increase the amount of remaining α' (stress-induced martensite). Namely, it is possible to control metallographic structure of the stainless

steel by the tension.

[0022] It should be noted that when the tension is excessive, γ-phase in unrecrystallized portion is transformed to α'-phase during the cooling. It is assumed that γ-phase in the unrecrystallized portion causes stress-induced martensitic transformation (α') at a predetermined temperature or less during cooling by remaining processing strain as well as influence of tension. Therefore, the tension to be loaded must also be given within the predetermined range where the reverse transformation is designed.

[0023] (d) Further, in the production method, by setting the higher rolling reduction, final cold rolling can be carried out by crushing the compounds for microfabrication. This is one of the advantages to have adjustment of performance as a separate step (temper-annealing); it is essential to carry out the temper rolling at the predetermined processing rate for adjusting its performance.

[0024] Hereinafter, the present invention will be described.

[0025] The first aspect of the present invention is a stainless steel sheet for parts, which consists essentially of: 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, to total mass of the stainless steel as 100 mass %, Md value derived from the formula:

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying

within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, among compounds formed by the above components, indwelling content of the compounds whose maximum diameter is 20 μm or more being 30 or less per 5 g (mass) of the stainless steel, and the metallographic structure of the entire stainless steel being a mixed structure of recrystallized grain and unrecrystallized portion, so as to solve the above problems.

[0026] The second aspect of the invention is a stainless steel sheet for parts, which consists essentially of: 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, 0.02-0.24 mass % of N, as well as 0.5 mass % or less of one or more selected from Nb, Ti, and V, to total mass of the stainless steel as 100 mass %, Md value derived from the formula:

$$Md = 500 - 548(C + N) - 9(Si + Mn) - 14Cr - 20Ni - 65Nb - 27Ti - 61V$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, among compounds formed by the above components, indwelling content of the compounds whose maximum diameter is 20 μm or more being 30 or less per 5 g (mass) of the stainless steel, and the metallographic structure of the entire stainless steel being a mixed structure of recrystallized grain and unrecrystallized portion, so as to solve the above problems.

[0027] The third aspect of the invention is the stainless steel sheet for parts according to the first or second aspect

of the invention, wherein average grain diameter of the recrystallized grain is 10 μm or less.

[0028] The fourth aspect of the invention is the stainless steel sheet for parts according to the third aspect of the invention, wherein the mixed structure includes 70 mass % or more of austenitic phase.

[0029] The fifth aspect of the invention is a method for producing the stainless steel sheet for parts consisting essentially of 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, to total mass of the stainless steel as 100 mass %, Md value derived from the formula:

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, the method comprising the steps of: a first cold rolling for cold-rolling a material at least once; a first annealing being made a set together with the first cold rolling and provided after the first cold rolling; a second cold rolling being provided after the first annealing as the final rolling to make the rolling reduction to 20% or more and to make a total rolling reduction of the first cold rolling and the second cold rolling to 60% or more; a second annealing for holding the material treated by the second cold rolling at a temperature between 650-1000 °C for 300 seconds or less and tempering the material held at the temperature by imparting tension of 0.2% yield strength or less; and microfabrication of

rough inclusion by strengthening floatation-separation of the rough inclusion at a time of molding or using work rolls in small diameter at the final cold-rolling to reduce indwelling content of the compounds which are formed by the above components and whose maximum diameter is 20 μm or more to 30 or less per 5 g (mass) of the stainless steel.

[0030] The sixth aspect of the invention is a method for producing the stainless steel sheet for parts consisting essentially of 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, as well as 0.5 mass % or less of one or more selected from Nb, Ti, and V, to total mass of the stainless steel as 100 mass %, Md value derived from the formula:

$$Md = 500 - 548(C + N) - 9(Si + Mn) - 14Cr - 20Ni - 65Nb - 27Ti - 61V$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, the method comprising the steps of: a first cold rolling for cold-rolling a material at least once; a first cold rolling for cold rolling, at least once, a material a first annealing being made a set together with the first cold rolling and provided after the first cold rolling; a second cold rolling being provided after the first annealing as the final rolling to make the rolling reduction to 20% or more and to make a total rolling reduction of the first cold rolling and the second cold rolling to 60% or more; a second annealing for holding the material treated by the second cold rolling at a temperature between 650-1000 °C for 300 seconds or less and

tempering the material held at the temperature by imparting tension of 0.2% yield strength or less; and microfabrication of rough inclusion by strengthening floatation-separation of the rough inclusion at a time of molding or using work rolls in small diameter at the final cold-rolling to reduce indwelling content of the compounds which are formed by the above components and whose maximum diameter is 20 μm or more to 30 or less per 5 g (mass) of the stainless steel.

[0031] The seventh aspect of the invention is the method for producing the stainless steel sheet for parts according to the fifth or sixth aspect of the invention, wherein the tension of the second annealing is 40% or less of 0.2% yield strength of the material at the maintained temperature.

[0032] The eight aspect of the invention is the method for producing the stainless steel sheet for parts according to any one of the fifth to seventh aspects of the invention, the method further comprising a temper rolling after the second annealing (S4).

Effects of the Invention

[0033] According to the present invention, it is possible to provide the stainless steel sheet which can be used for producing various parts accurately with high reliability. The invention also provides a method for producing the stainless steel sheet. Particularly, by the invention, it is capable of industrially and stably providing the stainless steel sheet of the invention, which exhibits excellent formability, post-forming-fatigue property, and high-reliability, with

inexpensive price. Further, corresponding to the recent environmental issue, it is possible to develop effective use of resources by miniaturization and weight saving.

Brief Description of the Drawings

[0034]

Fig. 1 is a diagram for describing a mode of flow of the production method of the present invention;

Fig. 2 is a graph showing an example about relations between temperature of material and 0.2% yield strength;

Fig. 3 is a graph showing between degrees of hardness and elongation of the stainless steel sheet produced based on the results obtained from the present invention;

Fig. 4 is magnified photographs showing surface of bending portions in case of No. 4 and No. 28 of the invention;

Fig. 5 is a diagram for describing an example of production method of conventional stainless steel sheet; and

Fig. 6 is a diagram for describing another example of production method of conventional stainless steel sheet

Description of the reference numerals

[0035]

S1 first cold rolling step

S2 first annealing step

S3 second cold rolling step

S4 second annealing step

Best Mode for Carrying Out the Invention

[0036] The above effects and advantages of the inventions will be made apparent from the best mode for carrying out the invention, which will be described as follows.

[0037] Hereinafter, best mode of the invention and the preferable scope thereof will be described.

(1) Stainless steel sheet

First of all, the stainless steel sheet of the present invention will be described. As described above, in the stainless steel sheet of the invention, it has characteristics in the composition and structure, Md value, and conformation of the compounds contained therein. Now, each of the characteristics will be described.

[0038] (1-1) Components

Components contained in the present invention and the content will be described. The main component of the stainless steel sheet of the invention is Fe; contents shown below are the ratio to total mass of the stainless steel sheet as 100 mass %.

[0039] < C >

Content of C is within the range of 0.01-0.08 mass %. C is one of the inexpensive and effective interstitial solid-solution strengthening elements. When 0.01 mass % or more of C is contained, solid solution strengthening effect is attained. On the other hand, the upper limit is 0.08 mass %. Because C is a forceful γ-stabilizing element, excessive addition may inhibit necessary stress-induced martensitic (α') transformation. It is also because when a production method containing temper-annealing is adopted, rough and large carbide is deposited to the grain boundary represented by $Cr_{23}C_6$ compound at a time of

temper-annealing and that deteriorates workability as well as corrosion resistance. More preferable C content is within the range of 0.02-0.07 mass %.

[0040] < Si >

Content of Si is 0.1-2.0 mass %. Si is an effective solid-solution strengthening element. The reason for determining the lower limit to 0.1 mass % or more is because high-temperature strength is raised and that makes it possible to easily obtain the above mixed structure as the characteristic of the invention. The reason for determining the upper limit to 2.0 mass % is because, as Si is also a ferrite (α) stabilizing element, excessive addition increases α'-phase remained during temper-annealing. More preferable Si content is within the range of 0.2-1.8 mass %.

[0041] < Mn >

Content of Mn is 3.0 mass % or less. Mn is a γ-stabilizing element so that it is added in consideration for balance with other elements. The reason for determining the content to 3.0 mass % or less is because when excessively added, α'-phase cannot be obtained. Moreover, in the case, inclusions and the like are formed, which deteriorate the workability and corrosion resistance of the product. More preferable Mn content is within the range of 2.6 mass % or less.

[0042] < Cr >

Content of Cr is 10.0-20.0 mass %. Cr is one of the basic alloy elements of stainless steel. The reason for determining the content to 10.0 mass % or more is to obtain necessary corrosion resistance. The reason for determining the upper limit to 20.0

mass % is because Cr is a α-stabilizing element and excessive addition thereof causes increase of α'-phase remained after temper-annealing. More preferable Cr content is within the range of 13.0-19.0 mass %.

[0043] < Ni >

Content of Ni is 3.0-12.0 mass %. Ni is also the basic alloy elements of stainless steel. It is also the most effective γ-stabilizing element. The reason for determining the lower limit to 3.0 mass % is because the range is essential for obtaining γ-phase which is stable at room temperature. The reason for determining the upper limit to 12.0 mass % is because it is necessary to develop α'-transformation within the predetermined range. More preferable Ni content is within the range of 3.5-11.5 mass %.

[0044] < N >

Content of N is 0.02-0.25 mass %. Similar to C, N is one of the effective interstitial solid-solution strengthening elements so that it is capable of fusing into a state of solid-solution at higher temperature compared with the case of C without forming compound. In other words, it is the major strengthening element of the invention. From this point of view, the lower limit is the lower limit is determined to 0.02 mass %. The reason for determining the upper limit to 0.25 mass % is because excessive addition may deteriorate hot-workability and may interfere with production of the sheet. In addition, similar to C, N is one of the forceful γ-stabilizing elements, so it may inhibit α'-transformation. More preferable range of N content is 0.04-0.20%, furthermore preferably 0.08-0.02%, the most

preferably 0.10-0.20 mass %.

[0045] < Nb >

Content of Nb is 0.50 mass % or less. Nb enables to make itself deposit as Nb compound which is finely dispersed and is relatively stable even at high temperature, which enables to easily obtain the mixed structure. By inhibiting the grain growth, it is possible to make recrystallized grain finer. The reason for determining the upper limit to 0.50 mass % is because excessive addition forms rough compounds thereby deteriorates ductility of the material. Further, since Nb is an expensive substance, in view of cost, the upper limit is set. More preferable Nb content is within the range of 0.45 mass % or less.

[0046] < Ti >

Content of Ti is 0.50 mass % or less. Ti seems to show similar effect like Nb. Namely, precipitation of Ti compound enables to obtain mixed structure easily and enables to make recrystallized grain finer. Moreover, it is presumably possible to form the compound easily than the case of Nb. The reason for determining the upper limit to 0.50 mass % is because excessive addition forms rough compounds that results in decrease of ductility of the material. More preferable Ti content is within the range of 0.45 mass % or less.

[0047] < V >

Content of V is 0.50 mass % or less. V seems to show similar effect like Nb and Ti. Namely, precipitation of V compound enables to obtain mixed structure easily and enables to make recrystallized grain finer. The reason for determining the upper limit to 0.50 mass % is because excessive addition forms rough

compounds that results in decrease of ductility of the material. More preferable V content is within the range of 0.001 mass % or more and 0.45 mass % or less.

[0048] As required, other than the above components, elements added from the industrial aspect like Ca, Al, rare-earth metal (REM) these of which are used as deoxidizing agent at a time of molding, or B anticipated for improvement of hot-workability, may be contained such that total amount becomes 0.3 mass % or less. Further, in case where scrap is used as a material, inevitable Cu and Mo respectively may be contained within the range of 0.4 mass % or less. Cu and Mo in the invention act as adjusting elements for γ-stability. Inevitable impurities in the normal composition may be contained.

[0049] (1-2) Md value

Md value is calculated based on the following formula (1) or (2) shown in the present invention; the value is within the range of 0-80 °C. In should be noted that when at least one selected from the above Nb, Ti, V, each of which is not inevitable impurities, is added, formula (2) is used. When none of them is added, formula (1) is used. To the atomic symbols: C, N, Si, Mn, Cr, Ni, Nb, Ti, and V in the formulas, content (mass %) of corresponding component is substituted.

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni \quad (1)$$

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni - 65Nb - 27Ti - 61V \quad (2)$$

Md value is expressed as "°C" and shows frequency of stress-induced martensitic (α') transformation. The formula is formulated the temperature (30 °C), where 50% of the total

transforms to α'-phase when 30% tensile deformation is given to γ-monophase material, based on results of a series of experiment of the present invention. As above, the invention is intended for metastable γ-stainless steel and utilize α'-transformation, so it is necessary to control α'-transformation. Therefore, the optimal Md value for this is set to 0-80 °C. It is more preferably 10-70 °C.

[0050] (1-3) Conformation of the compounds

In the stainless steel sheet of the present invention, the compound contained in the stainless steel sheet, particularly the compound whose maximum diameter is 20 μm or more exists at a ratio of 30 or less per 5 g (mass) of the stainless steel sheet. Accordingly, it is possible to reduce defects attributed to the compounds. As it were, material of the invention has excellent formability; in addition, seemingly, probability where rough compounds exist in the vicinity of the sheet surface becomes extremely small. In the case of press working, convexo-concaves and minor cracks attributed to the large difference of deformability of the both (material and rough compound) can be improved. Moreover, in the case of etching, compound exposure attributed to the difference of corrosion resistance as well as occurrence of local defects such as holes (etch pit) caused by dropping can be prevented. As a result, machined surface of the parts becomes flat and smooth; whereby fatigue property is improved. The local defects are also presumably detected by measurement of surface roughness of the machined surface.

[0051] (1-4) Conformation of the structure

Structure of the material for the stainless steel sheet of

the present invention is a "mixed structure" defined by a structure in which recrystallized grain and unrecrystallized portion which leaves influence of the pre-working are mixed. By this structure, it becomes possible to be compatible with high-strength and high-ductility, but also to obtain higher-planarization and lower-residual stress can be possible. Moreover, the mixed structure may be a structure having 70 area % or more of γ-phase. By having the γ-phase as the main structure, formability and fatigue property can be further improved. More preferable ratio of the γ-phase is 80 area % or more.

[0052] By forming the stainless steel sheet as described above, it is possible to provide a stainless steel sheet which is excellent in various properties and also is possible to improve workability (formability, etchability) and fatigue property. In addition, grain diameter of the recrystallization may be 10 μm or less. As a consequent, formability and fatigue property attributed to the miniaturization of crystal grain can be further improved. More preferable grain diameter thereof is 6 μm or less.

[0053] (2) Method for producing stainless steel sheet

Secondly, a mode of the method for producing the stainless steel sheet of the present invention will be described. As shown in Fig. 1, the method for producing the stainless steel sheet of the invention includes the steps of: a first cold rolling (S1) for giving at least one cold rolling; a first annealing (S2) being made a set together with the first cold rolling (S1); a second cold rolling (S3); and a second annealing (S4) for giving annealing for the purpose of tempering. Each step will be described as follows.

[0054] (2-1) First cold rolling step (S1)

To the first cold rolling step (S1), materials, to which the above described components are added and hot-worked, are supplied. The step is provided to mainly make the dimension of the material closer to the dimensions of the finished steel sheet. Thus, it is not necessarily once, several times of rolling can be carried out. Specifically, rolling reduction of the first cold rolling step (S1) and the second cold rolling conducted later on is 60% or more, preferably 70% or more, more preferably 80% or more, and the most preferably 90% or more.

[0055] (2-2) First annealing step (S2)

This step is the one to be made a set together with the above first cold rolling step (S1); it is provided for softening and elongating the material as the main purpose. Therefore, any type of annealing which is normally carried out is not specifically restricted to. The condition may be determined depending on the material to be provided and confirmation of finally obtained steel sheet.

[0056] (2-3) Second cold rolling step (S3)

The second cold rolling step (S3) is provided after the above-described set of the first cold rolling step (S1) and the first annealing step (S2); this is the last cold rolling step. In the second cold rolling step (S3), thickness of the sheet is reduced to that of the finished stainless steel sheet. The reduction of thickness is expressed in rolling reduction at 20% or more and in a total rolling reduction of the first cold rolling and the second cold rolling at 60% or more. This is because if the rolling reduction is set at 20% or more, sufficient

stress-induced martensitic (α') phase can be obtained. Further, due to this, grain refining can be done. The rolling reduction is preferably at 30% or more. Moreover, the reason for setting the rolling reduction of total of the first cold rolling and the second cold rolling to 60% or more is to reduce the number of rough compounds having the grain diameter of 20 μm or more, by having lager rolling reduction to crush the compounds into finer pieces. Thereby, it becomes possible to make maximum diameter of the compounds smaller and to reduce the number of rough compounds having the grain diameter of 20 μm or more. In such a case, as it gives larger effect in crushing the rough compounds, it is preferable to carry out cold rolling by using work roll having a small diameter.

[0057] (2-4) Second annealing step (S4)

The second annealing step (S4) is the last annealing step; by this step, conformation of the materials of the finished stainless steel sheet can be determined. In particularly, in the step, annealing temperature is set at 650-1000 °C and holding time is set for 300 seconds or less. The conditions are provided in view of adjusting mechanical properties of the material, as well as productivity and impact on the metallographic structure of the material like grain growth. Under the conditions, the production is effective, and it is capable of obtaining a stainless steel sheet of high-planarization and low-residual stress.

[0058] Further, in the second annealing step (S4), when the temperature is raised up to the above annealing temperature, tension is given to the material. Greatness of the tension about

the material at the annealing temperature is 0.2% yield strength or less. It is more preferably 40% or less of the 0.2% yield strength. When the material is loaded with tension of the above greatness, reverse transformation thereof can be adjusted. Hence, the material can contain finer recrystallized grain and have a mixed structure having the γ-phase at higher ratio. Consequently, not only well-balanced strength and ductility can be imparted to the obtained stainless steel sheet, but also high-planarization and low-residual stress can be compatible. Fig. 2 is a graph showing an example about relations between temperature and 0.2% yield strength of the material. The tension is determined based on i.e. Fig. 2 and loaded.

[0059] The method for microfabrication of inclusion may preferably be a measure for strengthening floatation-separation of the rough inclusion at a time of molding. Specifically, there may be a method for carrying out floatation-separation of rough inclusion by extending the heating duration of the molten metal. Other than this, by carrying out the above first cold rolling step (S1) and the second cold rolling step (S2) with rolls of small diameter, it is possible to crush the rough inclusion into finer pieces. The above two methods may be combined; it is not specifically restricted as long as number of the compound whose maximum diameter is 20 μm or more contained in the stainless steel sheet can be reduced to 30 or less per 5 g (mass) of the stainless steel sheet. Furthermore, within the range that can maintain the distribution of inclusion for the invention to develop high-performance and effect of the mixed structure, in order to raise the strength and so on, temper rolling may be given after

the second annealing step.

[0060] By the production method of the stainless steel sheet for parts, it is possible to produce stainless steel sheet for parts of the present invention. In other words, the invention enables to produce the stainless steel sheet which is excellent in the above various properties and is possible to improve workability (formability, etchability) and fatigue property. Moreover, according to the production method, it is capable of industrially and stably providing the stainless steel sheet of the invention with inexpensive price.

Examples

[0061] Hereinafter, the invention will be more specifically described by way of the following examples. However, the present invention is not limited by the Examples. In the Examples, stainless steel sheets in the scope of the present invention and stainless steel sheets outside the scope of the invention were respectively produced and evaluated.

[0062] (i) Production of test material

Compositions of the test material are shown in Table 1. Among the compositions, some of the components whose value are outside the scope of the invention are marked with "*" on the right shoulder of numeric value of the content.

[0063] (Table 1)

(Table 1)

	Composition (mass %)									Md	Notes
Steel	C	Si	Mn	Cr	Ni	N	Nb	Ti	V	(°C)	
a	0.021	0.23	0.25	18.46	4.62	0.203	<0.001	<0.001	<0.001	42.2	-
b	0.025	0.48	1.28	17.08	6.83	0.118	<0.001	<0.001	<0.001	42.9	-
c	0.054	0.52	1.21	13.03	10.60	0.116	<0.001	<0.001	<0.001	12.2	-
d	0.027	0.49	1.27	17.09	6.87	0.110	0.295	<0.001	<0.001	25.6	-
e	0.026	0.50	1.25	17.14	6.88	0.119	<0.001	0.282	<0.001	32.7	-
f	0.024	0.52	1.29	17.02	6.94	0.121	<0.001	<0.001	0.276	23.4	-
g	0.127 *	0.53	1.12	25.01 *	2.01 *	0.042 *	<0.001	<0.001	<0.001	17.4 *	-
h	0.124 *	3.29 *	1.16	17.41	6.99	0.289 *	<0.001	<0.001	<0.001	-112.7 *	-
i	0.024	0.52	1.19	17.11	7.01	0.124	0.694 *	<0.001	<0.001	-8.0 *	-
j	0.021	0.49	1.31	17.14	6.91	0.127	<0.001	0.596 *	<0.001	21.8 *	-
k	0.118 *	0.61	1.12	17.09	7.04	0.060	0.002	0.001	0.001	22.6	SUS301steel
l	0.060	0.58	0.83	18.36	8.24	0.050	0.003	0.001	0.001	14.8	SUS304 steel

Md=500−458(C+N)−9(Si+Mn)−14Cr−20Ni
or
Md=500−458(C+N)−9(Si+Mn)−14Cr−20Ni−65Nb−27Ti−61V

[0064] About each material having a composition including components shown in "a to l" of Fig. 1, stainless steel sheets were produced in accordance with respective production conditions. Table 2 shows major conditions in the production process.

[0065] (Table 2)

(Table 2)

No.	Test steel			Production process				
	Steel	Measure for minimizing inclusion		Total Rolling reduction of 1st and 2nd Cold rolling (%)	2nd Cold rolling	2nd Annealing		
		Extension of heating duration	Use of small-diameter roll		Rolling reduction (%)	Temp. (°C)	Time (sec)	Tension (%)
1	a	Done	-	95	50	800	30	30
2	b	Done	-	95	50	900	30	30
3	b	Done	-	95	30	800	30	30
4	b	Done	-	95	50	800	30	30
5	b	Done	-	95	70	800	30	30
6	b	Done	-	95	50	800	180	30
7	b	Done	-	95	50	800	30	50
8	b	Done	-	95	50	800	30	70
9	b	Done	-	95	50	700	30	30
10	b	Done	Used	95	70	800	30	30
11	c	Done	-	95	30	900	30	30
12	c	Done	-	95	50	900	30	30
13	c	Done	-	95	50	800	30	30
14	d	Done	-	80	50	900	30	30
15	d	Done	-	80	50	800	30	30
16	e	Done	-	80	50	900	30	30
17	f	-	Used	80	50	900	30	30
18	b	Done	-	55 *	10 *	700	30	30
19	b	-	-	50 *	10 *	800	30	30
20	b	Done	-	95	50	1100 *	30	30
21	b	Done	-	95	50	600 *	30	30
22	g *	Done	-	80	50	900	30	30
23	h *	-	-	80	50	800	30	30
24	i *	-	-	80	50	800	30	30
25	j *	-	-	80	50	800	30	30
26	k *	Done	-	80	50	900	30	30
27	k *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	
28	k *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	
29	k *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	
30	l *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	
31	l *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	
32	l *	Done	-	-	Temper-rolling, shape correction		Straightening annealing at 500 °C for 300 sec	

[0066] The production method will be described in detail

with reference to Table 2. In Table 2, components whose numeric values are outside the scope of the invention are marked with "*". Steps before reaching cold rolling are common in each production condition. Specifically, molding small-sized ingot, cutting work, hot-rolling, annealing, and descaling (acid cleaning) were carried out. Moreover, about Examples shown as Nos. 1-16, No. 18, Nos. 20-22, Nos. 26-32 in Table 2, as measures for minimizing inclusion, heating duration of the molten metal was extended for strengthening floatation-separation of the rough inclusion at a time of molding.

[0067] Among the steel material thus obtained, with regard to the materials of Nos. 1-26, thickness of the sheet were adjusted by partial-cutting work and acid cleaning, and then, first cold rolling and annealing were carried out. Further, second cold rolling and second annealing were carried out based on the conditions shown in Table 2. Final thickness of the sheets was 0.2 mm. About examples shown in No. 10 and No. 17, for microfabrication of inclusion, small diameter of work rolls (60 mm in diameter) were used for cold rolling, compared with the work rolls of 200 mm in diameter used in other purposes than microfabrication of inclusion.

[0068] On the other hand, about the Examples of Nos. 27-32, as shown in Table 2, stainless steel sheets were treated by temper rolling to be 0.2 mm in thickness to have each hardness defined in the specification of JIS G4313. Thereafter, leveling by tension leveler and straightening annealing under the condition of heating at 500 °C for 300 seconds were carried out. Work roll used at the time of cold rolling was the one having diameter of

200 mm.

[0069] From the thin sheets having 0.2 mm in thickness obtained as above, test pieces were taken; then, various properties were researched and made comparison.

[0070] (ii) Evaluation items and the method for evaluation

Now, evaluation items and the method for evaluation are described.

< Distribution of compounds >

Firstly, a test piece of 5 g was taken and the parent material portion thereof was corroded and removed by 10% bromine-methanol solution. Following to this, residue products were extracted through a filter having predetermined dimension of holes and the residue products were observed by using scanning electron microscope (SEM) to count total number of the compounds having the maximum size of 20 μm or more.

[0071] < Grain diameter >

About the test pieces treated by attaching, polishing, and etching, the structure about a cross section parallel to the rolling direction (R.D.) was observed by using optical microscope and SEM. Meanwhile, thin film was produced and the structure was observed by using transmission electron microscope (TEM). A photograph of average structure in each test pieces were taken, and grain diameter was measured from these photographs. In addition to this, judgment whether or not the structure is a mixed structure was carried out.

[0072] It should be noted that grain diameter of Nos. 1-26 are shown by the value of recrystallized grain after temper-annealing, grain diameter of Nos. 27-32 are shown by the

value of recrystallized grain after second annealing step. Here, with respect to Nos. 27-32, since the grains thereof were deformed into wrought grains by temper rolling, the grain diameters are shown in brackets in Table 3. It was presumed that no change in grain diameter was made by straightening annealing.

[0073] < γ-phase ratio >

About the sheet surface, diffraction pattern was measured by using X-ray diffractometer; and then, ratio of γ-phase and α'-phase was calculated based on integral intensity rate of each phase peak.

[0074] < Hardness >

About sheet surface, hardness was measured at a load of 9.8 N by using a Micro-Vickers Hardness Tester.

[0075] < Elongation >

About JIS No. 13B type test piece for tensile test taken in parallel to the rolling direction (R.D.), elongation was measured by using an Instron-type tester.

[0076] < Surface roughness >

About the surface of bending outer circumference portion, before and after right-angled bend, within a bending radius of 2 mm of the substantially strip-shape test pieces which were taken in the direction perpendicular to the R.D., maximum height of the profile (Ry) of surface roughness were measured by using a laser microscope. Then, surface roughness was evaluated based on the value obtained from the following formula:

Increase rate (%) = 100 x (Ry after bending - Ry before bending)/(Ry before bending).

[0077] < Fatigue property >

Fatigue limit (the upper limit endurable for 107-time repeated bending) of the material where bending work had not been given was clarified by using a Reversed Plane-Bending Fatigue tester. Following to this, bending was repeatedly given to the test pieces used for bending for measurement of the above surface roughness under 90% stress of the fatigue limit of the material; and existence of cracks after 107-time repeated bending was observed. When cracked, it was evaluated by ×; when crack was not caused, it was evaluated by ○.

[0078] < Sheet warping >

In the example, flatness was evaluated by warping of the sheet. The method is as follows. About test pieces of 500 mm in length taken in parallel to the R.D., height of warping in a suspended state was visually measured before and after the temper-annealing or a combination of leveling and straightening annealing. Then, sheet warping was evaluated based on the value obtained from the following formula:

Reduction rate (%) = 100 x (warping after treatment - warping before treatment)/(warping before treatment).

[0079] < Residual stress >

About the taken test pieces, residual stress of sheet surface about R.D. was measured before and after the temper-annealing or a combination of leveling and straightening annealing, by using X-ray stress measurement device. Then, residual stress was evaluated based on the value obtained from the following formula:

Reduction rate (%) = 100 x (stress after treatment - stress before treatment)/(stress before treatment).

[0080] (iii) Results

Hereinafter, the results are described. Firstly, results about the composition and structure of the obtained stainless steel sheet will be described. The results are shown in Table 3.

[0081] (Table 3)

(Table 3)

No.	Steel	Compound	Structure			Notes
		Total number of compounds whose Max. diameter is 20μm or more	Structure	Recrystallized grain size (μm)	γ-phase ratio (%)	
1	a	8	Mixture	2	98	Example
2	b	6	Mixture	11	99	Example
3	b	10	Mixture	4	95	Example
4	b	6	Mixture	3	95	Example
5	b	8	Mixture	2	99	Example
6	b	6	Mixture	5	96	Example
7	b	6	Mixture	2	66	Example
8	b	6	Mixture	2	57	Example
9	b	6	Mixture	≦2	84	Example
10	b	0	Mixture	2	98	Example
11	c	13	Mixture	14	100	Example
12	c	4	Mixture	12	96	Example
13	c	4	Mixture	4	93	Example
14	d	11	Mixture	4	94	Example
15	d	11	Mixture	2	92	Example
16	e	9	Mixture	3	94	Example
17	f	24	Mixture	3	96	Example
18	b	26	Unrecrystallized *	- (none)	99	Comp. example
19	b	42 *	Mixture	16	91	Comp. example
20	b	6	Recrystallized *	22	100	Comp. example
21	b	6	Unrecrystallized *	- (none)	7	Comp. example
22	g *	18	Unrecrystallized *	- (none)	0	Comp. example
23	h *	32 *	Mixture	14	100	Comp. example
24	i *	50 *	Mixture	≦2	96	Comp. example
25	j *	34 *	Mixture	≦2	97	Comp. example
26	k *	12	Recrystallized *	16	100	Comp. example
27	k *	13	Unrecrystallized *	(24)	30	Comp. example
28	k *	8	Unrecrystallized *	(24)	10	Comp. example
29	k *	10	Unrecrystallized *	(24)	3	Comp. example
30	l *	8	Unrecrystallized *	(26)	60	Comp. example
31	l *	16	Unrecrystallized *	(26)	42	Comp. example
32	l *	20	Unrecrystallized *	(26)	30	Comp. example

※ note: "Example" means an example of the present invention.
"Comp. example" means a comparative example to the present invention.

[0082] As seen from Tables 2 and 3, about Nos. 1-17 satisfying the condition of production method of the present invention, in

each case, number of compounds whose maximum diameter is 20 μm or more were 30 or less, and it was capable of obtaining mixed structure. Whereas, about Nos. 18-32, all of them had problems such as: number of compounds whose maximum diameter is 20 μm or more were 30 or more; or the structure was not a mixed structure. Hence, effect of the production method of the invention can be seen significantly about the stainless steel sheet of the present invention.

[0083] Next, various properties of the obtained stainless steel sheet will be described. The results are shown in Table 4.

[0084] (Table 4)

(Table 4)

No.	Hard-ness (HV)	Elongation (%)	Increase rate of Surface roughness (%)		Bending fatigue property	Increase rate of Plate warping (%)	Increase rate of Residual stress (%)	Tempering symbol (JIS G4313)	Notes
			Etching	Bending					
1	370	43.6	-83	47	○	-84	-82	-	Example
2	311	46.6	-48	54	○	-92	-94	-	Example
3	382	42.4	-76	44	○	-83	-81	-	Example
4	396	42.9	-78	40	○	-82	-82	-	Example
5	404	38.2	-81	36	○	-79	-81	-	Example
6	361	46.8	-77	48	○	-86	-88	-	Example
7	399	33.9	-81	52	○	-89	-86	-	Example
8	402	32.9	-81	53	○	-92	-84	-	Example
9	443	31.9	-86	52	○	-81	-82	-	Example
10	398	46.3	-90	30	○	-82	-84	-	Example
11	297	48.6	-41	59	○	-92	-93	-	Example
12	302	43.7	-54	55	○	-90	-94	-	Example
13	339	49.8	-80	41	○	-87	-84	-	Example
14	329	52.8	-54	42	○	-87	-92	-	Example
15	401	39.5	-88	33	○	-84	-86	-	Example
16	376	45.3	-89	38	○	-85	-89	-	Example
17	382	41.7	-84	36	○	-88	-84	-	Example
18	211	48.2	148	392	×	-82	-83	-	Comp. example
19	283	39.5	169	319	×	-85	-84	-	Comp. example
20	192	51.8	81	218	×	-96	-98	-	Comp. example
21	461	15.8	75	462	×	-36	-39	-	Comp. example
22	328	16.4	-48	296	×	13	-46	-	Comp. example
23	520	4.1	189	892(×)	×	-46	-54	-	Comp. example
24	472	13.6	198	394	×	-92	-91	-	Comp. example
25	468	12.8	207	491(×)	×	-90	-93	-	Comp. example
26	246	32.5	169	277	×	-96	-94	-	Comp. example
27	340	34.2	79	221	×	-40	-38	301-1/2H	Comp. example
28	389	24.5	24	245	×	-36	-34	301-3/4H	Comp. example
29	473	8.9	64	324	×	-31	-18	301-H	Comp. example
30	295	30.8	48	205	×	-42	-42	304-1/2H	Comp. example
31	354	18.4	36	274	×	-38	-45	304-3/4H	Comp. example
32	394	7.2	50	358	×	-42	-40	304-H	Comp. example

※ note: "Example" means an example of the present invention.

"Comp. example" means a comparative example to the present invention.

[0085] Further, a relation between hardness and elongation is shown in Fig. 3 based on the results of Examples of the present invention. As seen from Table 4 and Fig. 3, Nos. 1-17 of Examples

of the invention shows higher-strength and higher-ductility compared with any of the Nos. 18-32 as Comparative examples.

[0086] Moreover, in the examples of the invention, increase ratio of maximum value of the surface roughness after bending becomes 60% or less so that improvement in formability is apparent with development of even deformation. Fig. 4 is photographs about the surface of sheets before-and-after the bending and the surface roughness (Ry) at the time. Specifically, about an Example of the present invention (No. 4) and a Comparative example (No. 28), photographs and surface roughness are shown in cases of flat sheet, bending radius of 2 mm, and bending radius of 0.5 mm. According to the photographs and values of Ry, effects of the present invention can be seen. Particularly, with regard to the flat sheet, although any of the stainless steel sheets show almost the same surface roughness, when bended, the surface roughness of each sheet shows various difference.

[0087] Further, in Table 4, bending fatigue property about the present invention is favorable. Therefore, it is capable of maintaining excellent fatigue property even after bending. As it were, by optimizing not only mixed structure but also distribution of indwelling compounds, even deformation is developed and defect caused by bending is decreased. As a result, it is assumed that the invention can show excellent formability and maintain high fatigue strength.

[0088] Meanwhile, about etchability, maximum value of the surface roughness decreases and defects like etch pit decreases in the worked surface; the surface tends to become smoother compared with the state before working. In other words, by the

present invention, workability together with etchability can also be improved so that it is possible to maintain high fatigue strength even if it is worked parts.

[0089] Further, increase ratio of warping and residual stress is small; in terms of residual stress, increase ratio dropped by 70% or more. Accordingly, the present invention shows significant effect in these properties.

[0090] In the Examples of the invention, about Nos. 2, 11, and 12, temper-annealing temperature is relatively high, diameter of recrystallized grains rise over 10 μm. As for Nos. 7 and 8, imparted tension rises over 40% of 0.2% yield strength; thereby γ-phase ratio of mixed structure becomes less than 70%. Due to this, although these Examples can obtain superior stainless steel sheets to those of Comparative examples, among the Examples, the balance between strength and ductility tends to be inferior. So, for Nos. 2, 11, and 12, similar to Nos. 14, 16, and 17, it is possible to inhibit grain growth by adding Nb, Ti, and V to improve the performance furthermore. About Nos. 7 and 8, similar to No. 10, the performance can be improved by diminishing the imparted tension.

[0091] As for Nos. 1-18, Nos. 20-22, and Nos. 26-32 in which microfabrication of inclusion were carried out, number of inclusion whose maximum diameter is 20 μm or more is within the scope of the present invention. Among the Examples of the invention, No. 10 using floatation of inclusion and work rolls of small diameter particularly show the best balance between strength and ductility as well as workability.

[0092] Whereas, compared with the Examples of the present

invention, the Comparative examples as described above are poor in balance between those strength and ductility. More specifically, content of the components and Md value of Nos. 18-21 meet the scope of the present invention; however, due to the lack of rolling reduction, Nos. 18 and 19 cause production of 30 or more of compounds whose maximum diameter is 20 μm or more. Consequently, since mixed structure is not formed, favorable properties are not obtained about these Comparative examples. Moreover, about Nos. 20 and 21, as temper-annealing temperature is out of the scope of the production method of the present invention; the mixed structure is not formed. Thereby, the workability and fatigue property of the products are equivalent to or less than those of conventional products. As materials of other Comparative examples do not also satisfy necessary composition, high performance cannot be obtained.

[0093] Further, Table 5 shows results of properties of the No. 2 material treated by temper rolling under rolling reduction at 10% and 20%. In Table 5, No. 2-a is a case where No. 2 is treated by temper rolling under 10% rolling reduction; similarly, No. 2-b is a case where No. 2 is treated by temper rolling under 20% rolling reduction. As a result, it becomes apparent that the material maintains excellent properties even after temper rolling.

[0094] (Table 5)

(Table 5)

No.	Hardness (HV)	Elongation (%)	Increase rate of Surface roughness (%)		Bending fatigue property	Increase rate of Plate warping (%)	Increase rate of Residual stress (%)	Temper-rolling (Rolling after 2nd Annealing)	Notes
			Etching	Bending				Rolling reduction (%)	
2-a	348	41.3	-46	70	O	-64	-50	10	Example
2-b	386	36.5	-78	40	O	-31	-23	20	Example

[0095] The above has described the present invention associated with the most practical and preferred embodiments thereof. However, the invention is not limited to the embodiments disclosed in the specification. Thus, the invention can be appropriately varied as long as the variation is not contrary to the subject substance and conception of the invention which can be read out from the claims and the whole contents of

the specification. It should be understood that stainless steel sheet for parts and the production method thereof with such an alternation are included in the technical scope of the invention.

CLAIMS

1. A stainless steel sheet for parts, which consists essentially of: 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, to total mass of the stainless steel as 100 mass %,

Md value derived from the formula:

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities,

among compounds formed by the above components, indwelling content of the compounds whose maximum diameter is 20 μm or more being 30 or less per 5 g (mass) of the stainless steel, and

the metallographic structure of the entire stainless steel being a mixed structure of recrystallized grain and unrecrystallized portion.

2. A stainless steel sheet for parts, which consists essentially of: 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, 0.02-0.24 mass % of N, as well as 0.5 mass % or less of one or more selected from Nb, Ti, and V, to total mass of the stainless steel as 100 mass %,

Md value derived from the formula:

$$Md = 500 - 548(C + N) - 9(Si + Mn) - 14Cr - 20Ni - 65Nb - 27Ti - 61V$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities,

among compounds formed by the above components, indwelling content of the compounds whose maximum diameter is 20 μm or more being 30 or less per 5 g (mass) of the stainless steel, and

the metallographic structure of the entire stainless steel being a mixed structure of recrystallized grain and unrecrystallized portion.

3. The stainless steel sheet for parts according to claim 1 or 2, wherein average grain diameter of the recrystallized grain is 10 μm or less.

4. The stainless steel sheet for parts according to claim 3, wherein the mixed structure includes 70 mass % or more of austenitic phase.

5. A method for producing the stainless steel sheet for parts consisting essentially of 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, to total mass of the stainless steel as 100 mass %,

Md value derived from the formula:

$$Md = 500 - 458(C + N) - 9(Si + Mn) - 14Cr - 20Ni$$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying

within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, the method comprising the steps of:

a first cold rolling for cold-rolling a material at least once;

a first annealing being made a set together with the first cold rolling step and provided after the first cold rolling;

a second cold rolling being provided after the first annealing as the final rolling to make the rolling reduction to 20% or more and to make a total rolling reduction of the first cold rolling and the second cold rolling to 60% or more;

a second annealing for holding the material treated by the second cold rolling at a temperature between 650-1000 °C for 300 seconds or less and tempering the material held at the temperature by imparting tension of 0.2% yield strength or less; and

microfabrication of rough inclusion by strengthening floatation-separation of the rough inclusion at a time of molding or using work rolls in small diameter at the final cold-rolling to reduce indwelling content of the compounds which are formed by the above components and whose maximum diameter is 20 μm or more to 30 or less per 5 g (mass) of the stainless steel.

6. A method for producing the stainless steel sheet for parts consisting essentially of 0.01-0.08 mass % of C, 0.1-2.0 mass % of Si, 3.0 mass % or less of Mn, 10.0-20.0 mass % of Cr, 3.0-12.0 mass % of Ni, and 0.02-0.24 mass % of N, as well as 0.5 mass % or less of one or more selected from Nb, Ti, and V, to total mass of the stainless steel as 100 mass %,

Md value derived from the formula:

$Md = 500 - 548(C + N) - 9(Si + Mn) - 14Cr - 20Ni - 65Nb - 27Ti - 61V$

by substituting values in mass % of the above respective components to be contained in the stainless steel sheet satisfying within the range of 0 to 80, and the remainder including chemical composition as inevitable impurities, the method comprising the steps of:

a first cold rolling for cold-rolling a material at least once;

a first cold rolling for cold rolling, at least once, a material

a first annealing being made a set together with the first cold rolling and provided after the first cold rolling;

a second cold rolling being provided after the first annealing as the final rolling to make the rolling reduction to 20% or more and to make a total rolling reduction of the first cold rolling and the second cold rolling to 60% or more;

a second annealing for holding the material treated by the second cold rolling at a temperature between 650-1000 °C for 300 seconds or less and tempering the material held at the temperature by imparting tension of 0.2% yield strength or less; and

microfabrication of rough inclusion by strengthening floatation-separation of the rough inclusion at a time of molding or using work rolls in small diameter at the final cold-rolling to reduce indwelling content of the compounds which are formed by the above components and whose maximum diameter is 20 μm or more to 30 or less per 5 g (mass) of the stainless steel.

7. The method for producing the stainless steel sheet for parts according to claim 5 or 6, wherein the tension of the second annealing step is 40% or less of 0.2% yield strength of the material at the maintained temperature.

8. The method for producing the stainless steel sheet for parts according to any one of claims 5 to 7, the method further comprising a temper rolling step after the second annealing.