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(54) **PROCESS FOR MANUFACTURING HIGH-CARBON ELECTRIC RESISTANCE WELDED STEEL PIPE, AND AUTOMOBILE PART**

VERFAHREN ZUR HERSTELLUNG EINES KOHLENSTOFFFREICHEN
WIDERSTANDSGESCHWEISSTES STAHLROHRS UND AUTOMOBILTEIL

PROCÉDÉ DE FABRICATION DE TUYAU EN ACIER À FORTE TENEUR EN CARBONE, SOUDÉ
PAR RÉSISTANCE ÉLECTRIQUE, ET PIÈCE AUTOMOBILE

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for producing high carbon electric resistance welded steel pipes or tubes and automotive parts preferable as hollow mechanical parts for automobiles and the like. The present invention especially relates to improvement in reliability in electric resistance welded parts.

BACKGROUND ART

[0002] The present invention relates to a method for producing high carbon electric resistance welded steel pipes or tubes preferable as hollow mechanical parts for automobiles and the like. The present invention especially relates to improvement in reliability in electric resistance welded parts.

[0003] Recently, from an aspect of preservation of global environment, improvement of fuel efficiency of automobiles has been strongly demanded. In accordance with this demanding, weight saving of an automotive body has been strongly oriented. Therefore, hollow raw materials have been used as raw materials for automobile parts instead of conventionally used solid materials. Particularly, considering their good dimension accuracy and small surface decarburization, the use of electric resistance welded steel pipe or tube of high carbon steel, which is high carbon steel for mechanical structural use, has been considered as the hollow raw materials for parts used for automobiles and the like on which a heat treatment is required.

[0004] However, since the high carbon steel for mechanical structural becomes to have more carbon content, the high carbon steel exhibits tendencies of increasing the strength, degrading the elongation, and developing the segregation. The segregated portion where C, Mn, P, or the like are strongly segregated, has hot workability at high temperatures which considerably degraded. This makes the electric resistance welding itself difficult, or a defect such as hot cracking frequently occurs in the electric resistance welded part originated from the segregated portion. This leaves a problem in workability as a steel pipe or tube.

[0005] In order to solve the problem, for example, Patent Literature 1 discloses an electric resistance welded steel pipe or tube of mechanical structural high carbon steel. The mechanical structural high carbon steel contains, by mass%, C: 0.4 to 0.8%, Si: 0.15 to 0.35%, Mn: 0.3 to 2.0%, P: 0.030% or less, S: 0.035% or less, and Al: 0.035% or less, and further Mo: 0.05 to 0.15% is added. The balance is Fe and incidental impurities. The technique disclosed in Patent Literature 1 involves adding Mo to ensure substantially improving hot workability at 1000°C or more. This completes the steel electric resistance welded steel pipe or tube of mechanical structural high carbon steel excellent in hot workability.

[0006] Patent Literature 2 discloses a method for producing an electric resistance welded steel pipe or tube of high carbon steel with high workability. The method produces the electric resistance welded steel pipe or tube using a hot-rolled coil of high carbon steel as the raw material. The hot-rolled coil is obtained by hot-rolling a high-carbon steel slab. The high-carbon steel slab contains, by mass%, C: 0.3 to 0.6%, Si: 0.15 to 0.35%, Mn: 0.3 to 1.5%, P: 0.012% or less, S: 0.035% or less, and Al: 0.035% or less. The P concentration at the center segregation part of the high-carbon steel slab on which the continuous cast is performed is adjusted to the low level while satisfying the specific relationship with the C concentration. According to the technique disclosed in Patent Literature 2, the hot cracking during the electric resistance welding is restrained, and the yield is improved. According to the technique disclosed in Patent Literature 2, even if a severe treatment such as bulge forming is performed, a possibility of embrittlement crack of the segregated portion is low. The technique improves the workability of the electric resistance welded steel pipe or tube of high carbon steel.

[0007] Patent Literature 3 discloses the method for producing an electric resistance welded steel pipe or tube of mechanical structural high carbon steel with high workability. The method involves performing continuous cast on the high carbon steel that contains, by mass%, C: 0.30 to 0.60% and P: 0.012% or less, to form high-carbon steel slab whose P concentration at the center segregation part is adjusted to the low level while satisfying the specific relationship with the C concentration. This high-carbon steel slab is hot-rolled to obtain a hot-rolled coil of high carbon steel as the raw material. The hot-rolled coil is formed into a cylindrically-shaped open pipe by the forming roll group. After the forming, preferably, both edges of the open pipe are preheated at the heating width of 2 to 4 mm, which is wider than usual, and at 800 to 1000°C. The electric resistance welding is performed on both edges of the open pipe, and subsequently the electric resistance welded part is air-cooled. According to the technique disclosed in Patent Literature 3, the hot cracking during the electric resistance welding is restrained, the yield is improved, and further reduces the hardness of the electric resistance welded part. Accordingly, even if a severe treatment such as the bulge forming is performed, the method can prevent a crack of the welded part, improving the workability of the electric resistance welded steel pipe or tube of high carbon steel.

[0008] Patent Literature 4 discloses a method for heat treatment of an electric resistance welded part. The method involves performing the electric resistance welding on the electric resistance welded steel pipe or tube with the composition

containing C: 0.03 to 0.30%, Si: 0.50 to 3.00%, and Mn: 0.30 to 3.00%. After the welding, the welded part is heated to 800 to 1000°C and then is rapidly cooled from the Ar₃ transformation point or more at 20 to 200°C/s. Thus, the method causes the retained austenite to remain in the electric resistance welded part to enhance the workability of the electric resistance welded part. The technique disclosed in Patent Literature 4 improves the ductility of the electric resistance welded part and produces the electric resistance welded steel pipe or tube that can endure the severe treatment such as hydro forming.

CITATION LIST

PATENT LITERATURE

[0009]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 04-263039

Patent Literature 2: Japanese Unexamined Patent Application Publication No. 11-156433

Patent Literature 3: Japanese Unexamined Patent Application Publication No. 11-226634

Patent Literature 4: Japanese Unexamined Patent Application Publication No. 11-323442

[0010] EP2578712 discloses a method for manufacturing electric resistance welded steel pipes by cold drawing, normalizing (950°C x 10 min), subsequently forming into a shape of hollow drive shaft, and thereafter hardening by high-frequency heating.

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0011] Nowadays, especially from the aspect of ensuring safety of automobiles and the like, maintaining high reliability has been strictly requested for the parts for automobiles and the like. Especially, to use the electric resistance welded steel pipe or tube as the raw material for parts, the electric resistance welded steel pipe or tube has been requested to include an electric resistance welded part having reliability higher than the conventional ones. However, the techniques disclosed in Patent Literatures 1 to 4 have a problem that there is a case occurs which fails to fully satisfy requisite performance for reliability, which is represented by fatigue strength of the electric resistance welded parts.

[0012] The object of the present invention is to provide a method for producing an electric resistance welded steel pipe or tube of high carbon steel that includes an electric resistance welded part excellent in reliability by solving the problems. Here, "excellent in reliability" means the case where a defect that affects a fatigue strength is absent from the electric resistance welded part. Specifically, "excellent in reliability" means the following situation. Assume that an ultrasonic flaw detection test is conducted under the following conditions. The notch at depth: 0.2 mm × length: 12.5 mm is employed as a criterion. Section UA in JIS G 0582 "Automated ultrasonic examination of steel pipes and tubes" is applied to the ultrasonic flaw detection method. To detect a flaw of a fine defect at higher sensitivity, sensitivity enhancement of 6 decibels is conducted. As the result, the number of defects is 0. Further, a crack does not occur in the torsion fatigue test. The torsion fatigue test is conducted on the outer surface at the torsional stress τ of 350 MPa and the number of repeats of up to two millions.

SOLUTIONS TO THE PROBLEMS

[0013] In order to achieve the above-described object, long and intensive research was carried out by the inventors of the present invention on the causes of low reliability in the conventional electric resistance welded steel pipes or tubes of high carbon steel. As a result, they have found that the conventional electric resistance welded steel pipes or tubes of high carbon steel are likely to leave a defect such as a crack in the electric resistance welded part. Due to a necessity of highly accurate adjustment to be a predetermined dimensional shape, usually, a cold-sizing and a cold-straightening are performed on the conventional electric resistance welded steel pipe or tube of high carbon steel after terminating the electric resistance welding. These reducing and straightening possibly crack the electric resistance welded part hardened by the electric resistance welding, resulting in degrading the reliability.

[0014] Therefore, the following treatments are considered for the electric resistance welded steel pipe or tube of high carbon steel. After terminating the electric resistance welding, only the electric resistance welded part is normalized. Afterwards, treatments such as the sizing and the straightening are performed in cold. However, even this method fails to obtain the improvement in sufficient reliability. Although the cause is not apparent at the moment, it is guessed that defects such as shrinkage cavities are more likely to relate to the cause. The ground is considered as follows. The

electric resistance welding on the low-carbon steel usually squeezes the welded part with a squeeze roll to prevent the defects such as shrinkage cavities. However, since the electric resistance welding on the high carbon steel is performed at a low melting point, this causes a melting section to remain even after the high carbon steel passes through the squeeze roll. Accordingly, the defects such as shrinkage cavities are likely to occur in some cases.

[0015] Thus, the inventors have concluded that, to further improve the reliability in the electric resistance welded steel pipe or tube of high carbon steel, performing a treatment (reducing) to squash the defects such as shrinkage cavities occurring in the electric resistance welded part is necessary in addition to simply performing a heat treatment on the electric resistance welded part to improve the ductility.

[0016] From the results of further examinations, the inventors have found the following as effective. For the further improvement in reliability in the electric resistance welded steel pipe or tube of high carbon steel, the treatment in cold, such as a correction, immediately after the electric resistance welding is minimized as much as possible. Then, the electric resistance welded steel pipe or tube is reheated and hot-reducing rolling is performed in a temperature range of 850°C or more and at a reducing rate of diameter of 10% or more. The inventors have also perceived the following. The use of induction heating for reheating ensures shortening the heating time and ensures restraining decarburization.

[0017] The following describes experimental results, which are the basis for the present invention.

[0018] A high carbon steel sheet (sheet thickness: 7.9 mm) with a composition of containing, by mass%, C: 0.37%, Si: 0.25%, Mn: 1.50%, Al: 0.025%, N: 0.004%, Ti: 0.02%, and B: 0.002% was used as a raw material steel sheet. Using a plurality of rolls, the high carbon steel sheet was cold-formed into an approximately cylindrical shape. The mutually opposed end surfaces were butted and the electric resistance welding was performed, thereby forming electric resistance welded steel pipes or tubes (outer diameter: 89.1 mm ϕ). After the electric resistance welding was performed, the electric resistance welded steel pipe or tube was cold-reduced by a sizer rolling mill in cold at the reducing rate of 0 to 1.2%. An ultrasonic inspection was conducted on the obtained electric resistance welded steel pipe or tube, especially on the electric resistance welded part, to measure the number of defect portions (the number of defects). The ultrasonic flaw detection was conducted using a notch of depth: 0.2 mm $\times$ length: 12.5 mm as a criterion and performing sensitivity enhancement of 6 decibels. FIG. 1 illustrates the obtained results.

[0019] It has been found from FIG. 1 that the excess of the reducing rate of cold-reducing of 0.8% generates the defect remarkably.

[0020] After the electric resistance welding, the cold-reducing was performed at the reducing rate of cold-reducing: 0.1%, and after the cold-reducing, the electric resistance welded steel pipe or tube was immediately reheated to 980°C to change the reducing rate of diameter in the temperature range of 850°C or more up to 0 to 35%, thereby performing the hot-reducing rolling. The ultrasonic inspection was conducted on the electric resistance welded parts of the obtained electric resistance welded steel pipes or tubes, and the numbers of defect portions (the number of defects) were measured. The conditions on the ultrasonic inspection were similar to the conditions after the electric resistance welding. FIG. 2 illustrates the obtained results. The following has been found from FIG. 2. The hot-reducing rolling at the reducing rate of diameter of less than 10% exhibited defects remarkably in the electric resistance welded part. The excess of the reducing rate of diameter of 10% remarkably reduces the defects.

[0021] The present invention has been completed by adding further examinations based on the knowledge. That is, the gist of the present invention is as follows.

(1) A method for producing an electric resistance welded steel pipe or tube of high carbon steel, including the steps of: forming a raw material steel sheet into an approximately cylindrical shape by a cold working; and subsequently, performing a butt electric resistance welding on opposed end surfaces to form an electric resistance welded steel pipe or tube, wherein the raw material steel sheet is a high carbon steel sheet which has a composition consisting of, by mass%, C: 0.30 to 0.60%, Si: 0.05 to 0.50%, Mn: 0.30 to 2.0%, Al: 0.50% or less, and N: 0.0100% or less, optionally one element or two or more elements selected from the group consisting of Cu: 1.0% or less, Ni: 1.0% or less, Cr: 1.2% or less, Mo: 1.0% or less, and W: 1.5% or less, optionally one element or two or more elements selected from the group consisting of Ti: 0.04% or less, Nb: 0.2% or less, and V: 0.2% or less and optionally B: 0.0005 to 0.0050%, and the balance is Fe and incidental impurities, and wherein the method further includes the steps of: after the butt electric resistance welding, performing a cold-reducing at a reducing rate of 0.8% or less; subsequently, immediately after the cold-reducing, reheating or cooling and reheating; and performing a hot-reducing rolling in a temperature range of 850°C or more at a reducing rate of diameter of 10% or more.

(2) The method according to (1), wherein the reheating is a heating by high-frequency induction heating means.

(3) An automotive part, wherein the automotive part is produced using an electric resistance welded steel pipe or tube of high carbon steel as a raw material and the electric resistance welded steel pipe or tube of high carbon steel is produced using the method according to (1) or (2).

(4) The automotive part according to (3), wherein the automotive part is any one of a front fork, a rack bar, a drive shaft, a tie rod, a stator shaft, and a cam shaft.

EFFECTS OF THE INVENTION

[0022] The present invention allows obtaining an electric resistance welded steel pipe or tube of high carbon steel that includes an electric resistance welded part where a defect is restrained and that features excellent reliability. As a result, the present invention remarkably improves the reliability in the electric resistance welded steel pipe or tube of high carbon steel. The present invention also improves the reliability in hollow parts formed by using the electric resistance welded steel pipe or tube of high carbon steel as a raw material, for example, various automotive parts, such as front forks, rack bars, drive shafts, tie rods, stator shafts, and cam shafts or the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

FIG. 1 is a graph illustrating an influence of a reducing rate of cold-reducing exerted on the number of defects in an electric resistance welded part; and

FIG. 2 is a graph illustrating an influence of a reducing rate of diameter of hot-reducing rolling exerted on the number of defects in the electric resistance welded part.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0024] The present invention is a method for producing an electric resistance welded steel pipe or tube of high carbon steel. The present invention produces the electric resistance welded steel pipe or tube of high carbon steel employing a high carbon steel sheet as a raw material steel sheet and applying a commonly used method for producing the electric resistance welded steel pipe or tube. Here, the "steel sheet" includes a steel strip.

[0025] First, there will be described the reasons why the chemical composition of the high carbon steel sheet, which is the raw material steel sheet, is limited. Hereinbelow, mass% is written simply as % unless otherwise mentioned.

[0026] The steel sheet used as the raw material steel sheet in the present invention contains C: 0.30 to 0.60%, Si: 0.05 to 0.50%, Mn: 0.30 to 2.0%, Al: 0.50% or less, and N: 0.0100% or less. The steel sheet used as the raw material steel sheet in the present invention may contain one element or two or more elements selected from the group consisting of Cu: 1.0% or less, Ni: 1.0% or less, Cr: 1.2% or less, Mo: 1.0% or less, and W: 1.5% or less. The steel sheet used as the raw material steel sheet in the present invention may contain one element or, two or more elements selected from the group consisting of Ti: 0.04% or less, Nb: 0.2% or less, and V: 0.2% or less. The steel sheet used as the raw material steel sheet in the present invention may contain B: 0.0005 to 0.0050%. The balance other than the required components and the optional components is Fe and incidental impurities. From an aspect of discharging oxide from the electric resistance welded part, to improve the reliability in the electric resistance welded part, the sheet thickness of the raw material steel sheet is preferably 8 mm or less.

C: 0.30 to 0.60%

[0027] C is an element which becomes in solid solution state or which is precipitated as carbide or carbonitride to contribute to the increase in strength. To ensure desired steel pipe strength and steel pipe strength after heat treatment with such effect, the C content is designed to be 0.30% or more. Here, the "desired steel pipe strength" is defined as tensile strength TS: 1200 MPa or more. Meanwhile, the excess of the C content of 0.60% degrades the toughness after the heat treatment. For this reason, the C content is limited to the range of 0.30 to 0.60%.

Si: 0.05 to 0.50%

[0028] Si is an element that serves as a deoxidizing agent. To obtain such effect, the Si content is designed to be 0.05% or more. Meanwhile, the excess of Si content of 0.50% saturates the effect and is economically disadvantageous. Additionally, the excess promotes the generation of inclusions during the electric resistance welding, adversely affecting the soundness of the electric resistance welded part. For this reason, the Si content is limited to the range of 0.05 to 0.50% and is preferably 0.10 to 0.30%.

Mn: 0.30 to 2.0%

[0029] Mn is an element which becomes in solid solution state to increase the strength, contributing to improvement in hardenability. To obtain such effect, the Mn content is designed to be 0.30% or more. Meanwhile, the excess of the Mn content of 2.0% forms retained austenite, degrading the toughness after tempering. For this reason, the Mn content

is limited to the range of 0.30 to 2.0% and is preferably 0.8 to 1.6%.

Al: 0.50% or less

[0030] Al is an element that serves as a deoxidizing agent. To obtain such effect, the Al content is preferably designed to be 0.01% or more. Meanwhile, the excess of the Al content of 0.50% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. Additionally, this promotes the generation of inclusions during the electric resistance welding, adversely affecting the soundness of the electric resistance welded part. For this reason, the Al content is limited to the range of 0.50% or less and is preferably 0.02 to 0.04%.

N: 0.0100% or less

[0031] N is an effective element to form nitride or carbonitride to ensure the strength after heat treatment (tempering). To obtain such effect, the N content is preferably designed to be 0.0005% or more. The excess of the N content of 0.0100% forms a coarse nitride, possibly degrading the toughness and a fatigue resistance life. Accordingly, the N content is limited to 0.0100% or less. In the case of N containing Ti, from the relationship with the Ti content, adjusting N so as to meet the following expression is preferable.

$$N/14 \leq Ti/47.9$$

(Here, N and Ti are the contents (mass%) of the respective elements.)

[0032] The components described above are basic components of the steel sheet, which will be the raw material steel sheet. In addition to these basic components, the electric resistance welded steel pipes or tubes of the invention may as necessary further contain one element or two or more elements selected from the group consisting of Cu: 1.0% or less, Ni: 1.0% or less, Cr: 1.2% or less, Mo: 1.0% or less, and W: 1.5% or less; and/or one element or two or more elements selected from the group consisting of Ti: 0.04% or less, Nb: 0.20% or less, and V: 0.20% or less; and/or B: 0.0005 to 0.0050%.

[0033] One element or, two or more elements selected from the group consisting of Cu: 1.0% or less, Ni: 1.0% or less, Cr: 1.2% or less, Mo: 1.0% or less, and W: 1.5% or less

[0034] All the Cu, Ni, Cr, Mo, and W are elements contributing to improvements of the increase in strength and hardenability. The steel sheet, which will be the raw material steel sheet, can contain one element or two or more elements selected from the group consisting of Cu, Ni, Cr, Mo, and W as necessary.

[0035] Cu is an element which becomes in solid solution state to contribute to the increase in strength and the improvement in hardenability. Furthermore, Cu also improves toughness, delayed fracture resistance, and corrosion fatigue resistance. To obtain such effect, the Cu content is preferably designed to be 0.05% or more. Meanwhile, the excess of the Cu content of 1.0% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous and deterioration of workability. Accordingly, in the case of containing Cu, Cu is preferably limited to 1.0% or less and is more preferably 0.05 to 0.25%.

[0036] Ni is an element which becomes in solid solution state to contribute to the increase in strength and the improvement in hardenability. Furthermore, Ni also contributes to the improvements in toughness, delayed fracture resistance, and corrosion fatigue resistance. To obtain such effect, the Ni content is preferably designed to be 0.05% or more. The excess of the Ni content of 1.0% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous and deterioration of workability. Accordingly, in the case of containing Ni, the Ni content is preferably limited to 1.0% or less and is more preferably 0.05 to 0.25%.

[0037] Cr becomes in solid solution state to contribute to the increase in strength and the improvement in hardenability. Furthermore, Cr generates fine carbides, and by performing precipitation strengthening on Cr, Cr contributes to the increase in strength. To obtain such effect, the Cr content is preferably designed to be 0.1% or more. Meanwhile, the excess of the Cr content of 1.2% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. Additionally, the excess is likely to generate inclusions during the electric resistance welding, adversely affecting the soundness of the electric resistance welded part. Accordingly, in the case of containing Cr, the Cr content is preferably limited to 1.2% or less and is more preferably 0.1 to 0.5%.

[0038] Mo becomes in solid solution state to contribute to the increase in strength and the improvement in hardenability. Furthermore, Mo generates fine carbides, and by performing precipitation strengthening on Mo, Mo contributes to the increase in strength. To obtain such effect, the Mo content is preferably contained to be 0.01% or more. Meanwhile, the excess of the Mo content of 1.0% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. This forms coarse carbides, possibly resulting in deterioration of toughness. Accordingly, in the case of containing Mo, the Mo content is preferably limited to 1.0% or less and is more preferably

0.10 to 0.30%.

[0039] W also becomes in solid solution state to contribute to the increase in strength and improvement in hardenability. In addition thereto, W has an effect of properly balancing the hardness and toughness after the heat treatment. To ensure such effect, the W content is preferably designed to be 0.01% or more. Meanwhile, the excess of the W content of 1.5% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. For this reason, in the case of containing W, W is preferably limited to 1.5% or less and is more preferably 0.10 to 0.30%.

[0040] One element or two or more elements selected from the group consisting of Ti: 0.04% or less, Nb: 0.20% or less, and V: 0.20% or less

[0041] Ti, Nb, and V are all the elements that form fine carbides to contribute to the increase in strength. One element or two or more elements of Ti, Nb, and V can be selected and contained as necessary.

[0042] Ti is an element that has an effect of ensuring a solid solution B, which is effective to improve the hardenability, by coupling with N and fixing N, in addition to the above-described effects. Ti forms fine nitrides and has an effect of restraining grain coarsening during the heat treatment and the electric resistance welding, contributing to the improvement in toughness. To obtain such effect, the Ti content is preferably designed to be 0.001% or more. Meanwhile, the excess of the Ti content of 0.04% increases the inclusions, possibly resulting in deterioration of toughness. Accordingly, in the case of containing Ti, the Ti content is preferably limited to 0.04% or less. In the case of containing Ti, it is preferable to contain Ti so as to satisfy the following expression in the relationship with the N content. Ti is more preferable to be 0.01 to 0.03%.

$$N/14 \leq Ti/47.9$$

[0043] (Here, N and Ti are the contents (mass%) of the respective elements.)

[0044] Nb has an effect of forming fine carbides during tempering to contribute to the increase in strength. Nb also has an effect of refining a structure after the heat treatment to improve the toughness and delayed fracture resistance. To obtain such effect, the Nb content is preferably designed to be 0.001% or more. Meanwhile, the excess of the Nb content of 0.20% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. Accordingly, in the case of containing Nb, Nb is preferably limited to 0.20% or less and is more preferably 0.01 to 0.02%.

[0045] V forms fine carbides during tempering to contribute to the increase in strength. To ensure such effect, the V content is preferably designed to be 0.001% or more. Meanwhile, the excess of the V content of 0.20% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. Accordingly, in the case of containing V, the V content is preferably limited to 0.20% or less and is more preferably 0.01 to 0.08%.

B: 0.0005 to 0.0050%

[0046] Containing a trace of B improves the hardenability, properly balancing the hardness and toughness after the heat treatment. B strengthens the grain boundary, improving the quenching crack resistance. B can be contained as necessary. To obtain such effect, the B content is designed to be 0.0005% or more. Meanwhile, the excess of the B content of 0.0050% saturates the effect. Accordingly, the effect matching the content cannot be expected, resulting in economically disadvantageous. Additionally, the excess generates coarse B-containing precipitates, resulting in deterioration of the toughness. Accordingly, in the case of containing B, the B content is preferably limited in the range of 0.0005 to 0.0050%. The B content is more preferably 0.002 to 0.003%.

[0047] The balance other than the above-described components is Fe and incidental impurities. As the incidental impurities, P: 0.020% or less, S: 0.010% or less, and O: 0.005% or less are allowable.

P: 0.020% or less

[0048] P is an element that adversely affects the weld crack resistance and the toughness. The P content is preferably reduced within the range of 0.020% or less as much as possible. However, since the excessive reduction of the P content increases the refining cost, the P content is preferably 0.0005% or more and is more preferably 0.010% or less.

S: 0.010% or less

[0049] S is an element present as sulfide inclusions in steel. S adversely affects the workability, the toughness, and the fatigue life; and increases the reheat cracking sensitivity. The S content is preferably reduced as much as possible

in the range of 0.010% or less. However, since the excessive reduction increases the refining cost, the S content is preferably designed to be 0.0005% or more. The S content is more preferably 0.001% or less.

O: 0.005% or less

[0050] O (oxygen) is present as oxide inclusions in steel and adversely affects the workability, toughness, and fatigue life. Therefore, the O (oxygen) content is preferably reduced as much as possible within the range of 0.005% or less. The O content is more preferably 0.002% or less.

[0051] The present invention employs the high carbon steel sheet with the above-described composition as the raw material steel sheet. The method for producing the raw material steel sheet is not necessary to be especially limited. All the ordinary methods for producing a hot-rolled steel sheet are applicable. Slitting is performed on the raw material steel sheet so as to provide a predetermined width. The raw material steel sheet is continuously formed into an approximately cylindrical shape in cold preferably using a plurality of forming rolls. After forming, the opposed end surfaces are butted and the electric resistance welding is performed, thereby forming the electric resistance welded steel pipe or tube.

[0052] The present invention performs the electric resistance welding to form the electric resistance welded steel pipe or tube. After forming, this electric resistance welded steel pipe or tube is cold-reduced to prevent a defect of shape. The use of the sizer rolling mill is preferable for this rolling. The present invention limits the reducing rate of the cold-reducing to 0.8% or less. If the reducing rate exceeds 0.8%, a defect such as a crack occurs in the electric resistance welded part, resulting in degrading the reliability in the electric resistance welded part. In view of this, the reducing rate of the cold-reducing, which is performed after the electric resistance welding, was limited to 0.8% or less. The reducing rate is preferably 0.01 to 0.1%. It is preferable that the cold-reducing be not performed (the reducing rate: 0%) if a defect occurs in the electric resistance welded part. If not performing the cold-reducing, a probability of a failure occurring into a tube geometry is high. The reducing rate is defined as: (perimeter before sizing - perimeter after sizing)/perimeter before sizing $\times 100$ (%).

[0053] The electric resistance welded steel pipe or tube on which the cold-reducing has been performed at the reducing rate: 0.8% or less is immediately reheated or is cooled up to a room temperature and then is reheated. The temperature for reheating is not especially limited. In the present invention, the temperature for reheating is preferably a temperature in the temperature range of 850°C or more and at which the hot-reducing rolling can be performed with the reducing rate of diameter of 10% or more, namely, 900 to 1050°C.

[0054] In the present invention, the hot-reducing rolling is performed to ensure high toughness of the electric resistance welded part with reheating up to an austenite region and squash the defect generated at the electric resistance welded part. This ensures the defect to be harmless, thereby improving the reliability in the electric resistance welded part. If the finish rolling temperature of the hot-reducing rolling is less than 850°C, compression bonding of defects such as shrinkage cavities becomes insufficient. This fails to make the desired defect harmless. The finish rolling temperature of the hot-reducing rolling is preferably 900°C or more. The upper limit of the finish rolling temperature of the hot-reducing rolling is 1000°C at which coarsening of the structure can be prevented.

[0055] If the reducing rate of diameter of the hot-reducing rolling is less than 10% in the temperature range of 850°C or more, the reducing rate of diameter is insufficient, failing to make the desired defect harmless. Accordingly, the reducing rate of diameter of the hot-reducing rolling was limited to 10% or more. The reducing rate of diameter is preferably 30% or more. The upper limit of the reducing rate of diameter of the hot-reducing rolling is determined according to the desired dimensional shape. The reducing rate of diameter is defined as (outer diameter before rolling - outer diameter after rolling)/outer diameter before rolling $\times 100$ (%).

Example

[0056] The hot-rolled steel sheets (sheet thickness: 7.8 mm) of high carbon steel with the compositions shown in Table 1 were used as the raw material steel sheets. Slitting was performed on these raw material steel sheets so as to have the predetermined width. The raw material steel sheets were formed into approximately cylindrical-shaped open pipes in cold with a plurality of rolls. Afterwards, the opposed end surfaces were butted and the electric resistance welding was performed to form electric resistance welded steel pipes or tubes (headers) with outer diameter: 89.1 mm ϕ $\times$ wall thickness: 7.9 mm. After the electric resistance welding, the cold-reducing at the reducing rate shown in Table 2 was performed on the electric resistance welded steel pipes or tubes using the sizer rolling mill to adjust the electric resistance welded steel pipes or tubes to be a predetermined dimensional shape. After the cold-reducing, the electric resistance welded steel pipes or tubes were immediately heated up to the temperature shown in Table 2 by induction heating means. The hot-reducing rolling was performed under the conditions shown in Table 2 with hot-reducing rolling mill, and after the hot-reducing rolling, air cooling was performed. Thus, the electric resistance welded steel pipes or tubes at the outer diameter of 42.7 mm ϕ $\times$ wall thickness of 8.0 mm were formed.

[0057] The ultrasonic flaw detection was performed across the overall length (about 10000 m) of the electric resistance

welded parts of the obtained electric resistance welded steel pipes or tubes to examine the presentence/absence of detected defect and the number of defects (counted per the length of 10000 m) . The ultrasonic flaw detection was performed employing the notch at a depth: 0.2 mm $\times$ length: 12.5 mm as a criterion. The sensitivity enhancement of 6 decibels was performed.

[0058] Test materials were extracted from the obtained electric resistance welded steel pipes or tubes, and a cold-drawing was performed until the outer diameter: 36.7 mm ϕ $\times$ wall thickness: 7.2 mm were obtained. After the cold-drawing, a normalizing treatment (air cooling after heated to 945°C) and a quenching treatment (water-cooling and quenching after heated to 950°C) were performed. Torsion fatigue specimens (length: 500 mm) were extracted to conduct a torsion fatigue test.

[0059] The torsion fatigue test was conducted on ten pieces of specimens as follows. The torsional stress τ applied on the outer surface was set to 350 MPa. The test was conducted up to the number of repeats: two million times. Then, an incidence (%) of crack at the electric resistance welded part was measured. From these results (the results of the ultrasonic flaw detection and the torsion fatigue test), the reliability in the electric resistance welded part was evaluated. When the number of defects after the ultrasonic flaw detection was 0 and a crack was not generated by the torsion fatigue test, the result was determined as "Good." The results other than that were determined as "Poor." Thus, the reliability was evaluated.

[0060] Table 3 shows the obtained results.

[0061] All the examples of present invention exhibit a few defects at the electric resistance welded parts. The number of cracks at the electric resistance welded parts is also small in the torsion fatigue test. Meanwhile, the comparative examples, which are out of the scope of the present invention, exhibit a large number of defects at the electric resistance welded parts. The electric resistance welds were cracked many also in the torsion fatigue test.

[Table 1]

Raw material steel sheet No.	Chemical component (mass%)											Remarks
	C	Si	Mn	P	S	Al	N	O	Cr, Mo, W, Ni, Cu	Ti, Nb, V	B	
A	0.37	0.25	1.50	0.010	0.002	0.025	0.004	0.002	-	Ti: 0.02	0.002	Application example
B	0.41	0.25	1.50	0.010	0.002	0.025	0.004	0.002	-	-	-	Application example
C	0.41	0.25	1.50	0.008	0.002	0.025	0.004	0.002	Cr: 0.2	-	-	Application example
D	0.35	0.25	0.80	0.008	0.002	0.025	0.004	0.002	Cr: 1.0, Mo: 0.2	-	-	Application example
E	0.30	0.25	0.80	0.008	0.002	0.10	0.004	0.002	Cr: 1.0, Ni: 0.2, Cu: 0.2	Ti: 0.02, Nb: 0.02	0.002	Application example
F	0.37	0.25	1.50	0.008	0.002	0.025	0.004	0.002	-	V: 0.06	-	Application example
G	0.37	0.25	1.50	0.008	0.002	0.025	0.004	0.002	W: 0.20	-	-	Application example
H	0.37	0.25	1.50	0.010	0.002	0.025	0.004	0.002	Cu: 0.1, Ni: 0.1	Ti: 0.03	0.002	Application example
I	0.37	0.25	1.50	0.010	0.002	0.025	0.004	0.002	-	Nb: 0.02	0.002	Application example
J	0.37	0.25	1.50	0.010	0.002	0.025	0.004	0.002	Cu: 0.1, Ni: 0.1	Nb: 0.02	0.002	Application example

[Table 2]

Production condition No.	Cold-reducing*	Hot-reducing rolling				Remarks
	Reducing rate (%)	Heating temperature (°C)	Total reducing rate of diameter (%)	Reducing rate of diameter** (%)	Finishing rolling temperature (°C)	
a	0.01	980	52	52	850	Application example
b	0.1	980	52	52	850	Application example
c	0.2	980	52	52	850	Application example
d	0.4	980	52	52	850	Application example
e	0.6	980	52	52	850	Application example
f	0.8	980	52	52	850	Application example
g	<u>1.0</u>	980	52	52	850	Comparative example
h	<u>1.2</u>	980	52	52	850	Comparative example
i	0.1	-	-	-	-	Comparative example
j	0.1	980	52	6	800	Comparative example
k	0.1	980	52	8	800	Comparative example
l	0.1	980	52	10	800	Application example
m	0.1	980	52	20	800	Application example
n	0.1	980	52	25	800	Application example
o	0.1	980	52	30	800	Application example
p	0.1	980	52	35	800	Application example
*) The cold-reducing after the electric resistance welding by sizer rolling mill **) The reducing rate of diameter in the temperature region of 850°C or more						

[Table 3]

Steel sheet No.	Raw material steel sheet No.	Production condition No.	Ultrasonic flaw detection test	Torsion fatigue test	Reliability	Remarks
			Number of defects* (piece/10000 m)	Percentage of crack** (%)	Evaluation	
1	A	a	0	No crack	Good	Example of present invention
2	A	b	0	No crack	Good	Example of present invention
3	A	c	0	No crack	Good	Example of present invention
4	A	d	0	No crack	Good	Example of present invention
5	A	e	0	No crack	Good	Example of present invention
6	A	f	0	No crack	Good	Example of present invention
7	A	<u>g</u>	10	10	Poor	Comparative example
8	A	<u>h</u>	20	20	Poor	Comparative example
8	A	<u>i</u>	20	20	Poor	Comparative example
10	A	<u>j</u>	10	10	Poor	Comparative example
11	A	<u>k</u>	3	10	Poor	Comparative example
12	A	l	0	No crack	Good	Example of present invention
13	A	m	0	No crack	Good	Example of present invention
14	A	n	0	No crack	Good	Example of present invention
15	A	o	0	No crack	Good	Example of present invention
16	A	p	0	No crack	Good	Example of present invention
17	B	b	0	No crack	Good	Example of present invention
18	C	b	0	No crack	Good	Example of present invention
19	D	b	0	No crack	Good	Example of present invention
20	E	b	0	No crack	Good	Example of present invention

(continued)

Steel sheet No.	Raw material steel sheet No.	Production condition No.	Ultrasonic flaw detection test	Torsion fatigue test	Reliability	Remarks
			Number of defects* (piece/10000 m)	Percentage of crack** (%)	Evaluation	
21	F	b	0	No crack	Good	Example of present invention
22	G	b	0	No crack	Good	Example of present invention
23	H	b	0	No crack	Good	Example of present invention
24	I	b	0	No crack	Good	Example of present invention
25	J	b	0	No crack	Good	Example of present invention
*) Electric resistance welded part						
**) (Number of cracked specimens/number of total specimens) × 100(%)						

Claims

1. A method for producing an electric resistance welded steel pipe or tube of high carbon steel, comprising the steps of:

forming a raw material steel sheet into an approximately cylindrical shape by a cold working; and subsequently, performing a butt electric resistance welding on opposed end surfaces to form an electric resistance welded steel pipe or tube, wherein the raw material steel sheet is a high carbon steel sheet which has a composition consisting of, by mass%, C: 0.30 to 0.60%, Si: 0.05 to 0.50%, Mn: 0.30 to 2.0%, Al: 0.50% or less, and N: 0.0100% or less, optionally one element or two or more elements selected from the group consisting of Cu: 1.0% or less, Ni: 1.0% or less, Cr: 1.2% or less, Mo: 1.0% or less, and W: 1.5% or less, optionally one element or two or more elements selected from the group consisting of Ti: 0.04% or less, Nb: 0.2% or less, and V: 0.2% or less and optionally B: 0.0005 to 0.0050%, and the balance is Fe and incidental impurities, and wherein the method further comprises the steps of:

after the butt electric resistance welding, performing a cold-reducing at a reducing rate of 0.8% or less; subsequently, immediately after the cold-reducing, reheating or cooling and reheating; and performing a hot-reducing rolling in a temperature range of 850°C or more at a reducing rate of diameter of 10% or more.

2. The method according to claim 1, wherein the reheating is a heating by high-frequency induction heating means.
3. An automotive part, wherein the automotive part is produced using a high carbon electric resistance welded steel pipe or tube as a raw material and the high carbon electric resistance welded steel pipe or tube is produced using the method according to claim 1 or 2.
4. The automotive part according to claim 3, wherein the automotive part is any one of a front fork, a rack bar, a drive shaft, a tie rod, a stator shaft, and a cam shaft.

Patentansprüche

1. Verfahren zur Herstellung eines elektrisch widerstandsgeschweißten Stahlrohres oder einer -röhre aus hochkohlenstoffhaltigem Stahl, umfassend die Schritte:

Formen eines Ausgangsmaterial-Stahlblechs in eine etwa zylindrische Form durch Kaltumformen; und anschließend Durchführen eines elektrischen Stumpfwiderstandsschweißens an gegenüberliegenden Endflächen zum Bilden eines elektrisch widerstandsgeschweißten Stahlrohres oder einer -röhre, wobei das Ausgangsmaterial-Stahlblech ein hochkohlenstoffhaltiges Stahlblech ist, das eine Zusammensetzung aufweist, die, in Massen%, aus C: 0,30 bis 0,60 %, Si: 0,05 bis 0,50 %, Mn: 0,30 bis 2,0 %, Al: 0,50 % oder weniger und N: 0,0100 % oder weniger, optional ein Element oder zwei oder mehrere Elemente ausgewählt aus der Gruppe bestehend aus Cu: 1,0 % oder weniger, Ni: 1,0 % oder weniger, Cr: 1,2 % oder weniger, Mo: 1,0 % oder weniger und W: 1,5 % oder weniger, optional ein Element oder zwei oder mehrere Elemente ausgewählt aus der Gruppe bestehend aus Ti: 0,04 % oder weniger, Nb: 0,2 % oder weniger und V: 0,2 % oder weniger sowie optional B: 0,0005 bis 0,0050 % besteht und der Rest aus Fe und beiläufigen Verunreinigungen besteht und wobei das Verfahren weiterhin die Schritte:

Durchführen eines Kaltreduzierens bei einer Reduktionsrate von 0,8 % oder weniger nach dem elektrischen Stumpfwiderstandsschweißen; anschließend, unmittelbar nach dem Kaltreduzieren, Wiederaufheizen oder Abkühlen und Wiederaufheizen; und Durchführen eines warmreduzierenden Walzens in einem Temperaturbereich von 850°C oder mehr bei einer Durchmesserreduzierungsrate von 10% oder mehr

umfasst.

2. Verfahren gemäß Anspruch 1, wobei das Wiederaufheizen ein Aufheizen durch Hochfrequenzinduktionsheizmittel ist.

3. Automobilbauteil, wobei das Automobilbauteil unter Verwendung eines hochkohlenstoffhaltigen, elektrisch widerstandsgeschweißten Stahlrohres oder einer -röhre als ein Ausgangsmaterial hergestellt wird und das hochkohlenstoffhaltige, elektrisch widerstandsgeschweißte Stahlrohr oder die -röhre unter Verwendung des Verfahrens gemäß Anspruch 1 oder 2 hergestellt wird.

4. Automobilbauteil gemäß Anspruch 3, wobei das Automobilbauteil eines aus einer Vordergabel, einer Zahnstange, einer Antriebswelle, einer Spurstange, einer Leitradwelle und einer Nockenwelle ist.

Revendications

1. Procédé de fabrication d'un tube ou tuyau en acier soudé par résistance électrique constitué d'acier à haute teneur en carbone, comprenant les étapes consistant à :

former une tôle d'acier de matière première dans une forme approximativement cylindrique par un travail à froid ; et

ensuite, effectuer un soudage bout à bout par résistance électrique sur des surfaces d'extrémité opposées pour former un tube ou tuyau en acier soudé par résistance électrique,

dans lequel la tôle d'acier de matière première est une tôle d'acier à haute teneur en carbone qui a une composition constituée de, en % en masse, C : 0,30 à 0,60 %, Si : 0,05 à 0,50 %, Mn : 0,30 à 2,0 %, Al : 0,50 % ou moins et N : 0,0100 % ou moins, optionnellement un élément ou deux éléments ou plus choisis dans le groupe constitué de Cu : 1,0 % ou moins, Ni : 1,0 % ou moins, Cr : 1,2 % ou moins, Mo : 1,0 % ou moins et W : 1,5 % ou moins, optionnellement un élément ou deux éléments ou plus choisis dans le groupe constitué de Ti : 0,04 % ou moins, Nb : 0,2 % ou moins et V : 0,2 % ou moins et optionnellement B : 0,0005 à 0,0050 %, et le reste est Fe et les impuretés accidentelles, et le procédé comprenant en outre les étapes suivantes :

après le soudage bout à bout par résistance électrique, la réalisation d'une réduction à froid à un taux de réduction de 0,8 % ou moins ;

ensuite, immédiatement après la réduction à froid, un réchauffage ou un refroidissement et un réchauffage ; et

la réalisation d'un laminage de réduction à chaud dans une plage de température de 850 °C ou plus à un taux de réduction de diamètre de 10 % ou plus.

2. Procédé selon la revendication 1, dans lequel le réchauffage est un chauffage par des moyens de chauffage par induction haute fréquence.

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3. Pièce automobile, dans laquelle la pièce automobile est fabriquée en utilisant un tube ou tuyau en acier soudé à haute résistance électrique à haute teneur en carbone en tant que matière première, et le tube ou tuyau en acier soudé par résistance électrique à haute teneur en carbone est fabriqué selon la revendication 1 ou 2.

- 5 4. Pièce automobile selon la revendication 3, dans laquelle la pièce automobile est l'une quelconque parmi une fourche avant, une barre de crémaillère, un arbre d'entraînement, une barre d'accouplement, un arbre de stator et un arbre à cames.

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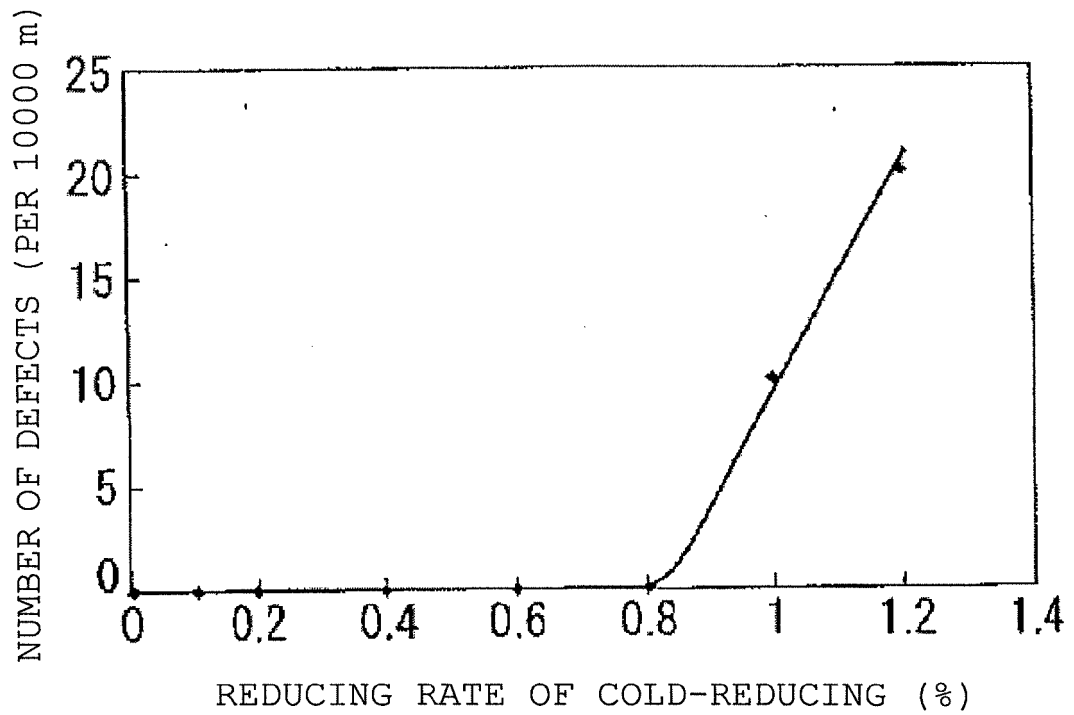
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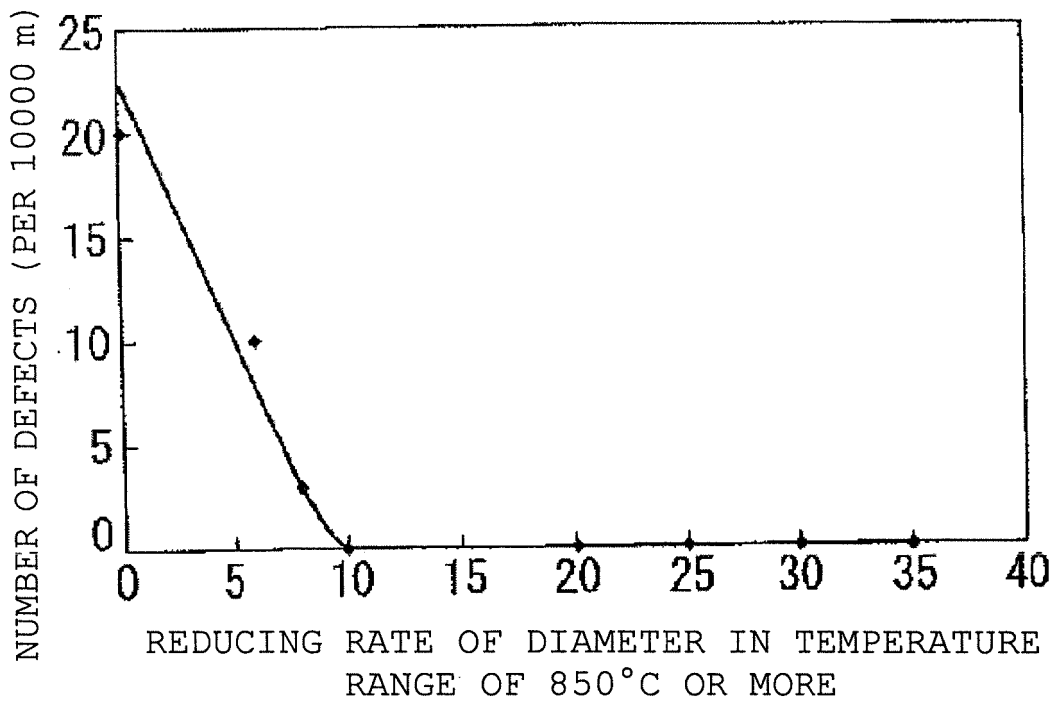
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[FIG. 1]



[FIG. 2]



REFERENCES CITED IN THE DESCRIPTION

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