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(54) ELECTRIC RESISTANCE WELDED STEEL PIPE FOR LINE PIPE EXCELLENT IN WELD PART TOUGHNESS
WIDERSTANDSGEWEBTES STAHLROHR FÜR LEITUNGSROHR MIT Hervorragender Schweisteilzähigkeit
TUYAU EN ACIER SOUDÉ PAR RÉSISTANCE ÉLECTRIQUE POUR TUBE DE CANALISATION PRÉSENTANT UNE EXCELLENTE RÉSISTANCE DES PARTIES SOUDÉES

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EP-A1-1 325 967
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US-B1-6 406 564


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Description

Technical Field

[0001] The present invention relates to electric resistance welded steel pipes with excellent weld toughness, in particular, to an electric resistance welded steel pipe with excellent weld toughness for a line pipe, the toughness being improved by focusing attention on minute defects (minute oxides and inclusions) that govern weld toughness and specifying the area fraction of the minute defects in the welds.

Background Art

[0002] A reduction in the toughness, in particular, impact absorption energy of steel products as the number of non-metal inclusions in steel is increased has often been investigated. For example, Non-Patent Document 1 describes MnS. In the case of carbides, Non-Patent Document 2 describes the effect of primary carbides in tool steel. The relationship between the non-metal inclusions and the impact absorption energy is generalized by regarding the non-metal inclusions as vacancy-type defects and is studied as the relationship between the defect size in steel and the impact properties. It appears that the impact properties are reduced as the size of the inclusions is increased. EP 1 325 967 discloses high strength steel pipe of APIX65 grade which has been electric resistance welded.

[0003] Meanwhile, with respect to electric resistance welded seams, oxides referred to as "penetrators", specifically, minute inclusions (in the form of an ellipse with a longitudinal diameter of 0.2 to 0.5 mm) present in welding faces by electric resistance welding, have been reported (Non-Patent Document 3). In general, impact properties of electric resistance welded seams have been said to be poor because of the presence of such penetrators. For the purpose of improving impact properties of electric resistance welded seams, there have been advances in a technique for reducing such penetrators. For example, heat input control relying on experience has been performed.

[0004] Disadvantageously, just reducing penetrators, which has been reported, does not necessarily improve impact properties.

Disclosure of Invention

[0005] In consideration of the foregoing circumstances, it is an object of the present invention to provide an electric resistance welded steel pipe for a line pipe, the electric resistance welded steel pipe having a high-toughness weld seam such that an electric resistance welded seam does not undergo brittle fracture. The invention is given in the claims. Broadly, the objects may be achieved by:-

1. In an electric resistance welded steel pipe with excellent weld toughness for a line pipe, the area fraction of minute defects each having a maximum length of less than 50 \( \mu \text{m} \) in a projection plane of an electric resistance welded seam is in the range of 0.000006 to 0.035, a V notch is formed on the electric resistance welded seam of a specimen for an impact test for metallic materials (V-notch Charpy test specimen) according to ISO/DIS 148-1 (JIS Z 2202), and the absorbed energy at -40\(^\circ\)C of the specimen measured by a method for impact test for metallic materials according to ISO 148 (JIS Z 2242) is 100 J or more.

2. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in item 1 contains, on a percent by mass basis, 0.01% to 0.15% C, 0.005% to 0.9% Si, 0.2% to 2.0% Mn, 0.01% or less P, 0.01% or less S, 0.1% or less Al, and the balance being substantially Fe.

3. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in item 2 further contains, on a percent by mass basis, one or two selected from 0.5% or less Cu and 0.5% or less Ni.

4. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in item 2 or 3,
5. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in any one of items 2 to 4, further contains, on a percent by mass basis, one or two or more selected from 0.1% or less Nb, 0.1% or less V, and 0.1% or less Ti.

6. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in any one of items 2 to 5, further contains, on a percent by mass basis, 0.005% or less Ca.

7. The electric resistance welded steel pipe with excellent weld toughness for a line pipe described in any one of items 1 to 6, in which the minute defects are composed of one or two or more selected from oxides, nitrides, and carbides remaining in a weld face when electric resistance welding is performed.

Advantages

[0006] According to the present invention, specifying the area fraction of minute defects in a welded seam results in an electric resistance welded steel pipe with excellent weld toughness.

Brief Description of Drawings

[0007]

[Fig. 1] Fig. 1 is a schematic diagram illustrating a C scan method.
[Fig. 2] Fig. 2 is a graph showing an exemplary relationship between the signal intensity and the defect size.
[Fig. 3] Fig. 3 is a graph showing an exemplary relationship between the signal intensity and the absorbed energy at -40°C.
[Fig. 4] Fig. 4 is a graph showing an exemplary relationship between the area fraction of minute defects in a weld seam and the absorbed energy at -40°C.
[Fig. 5] Fig. 5 is a schematic diagram illustrating array ultrasonic testing (array UT) of a weld seam using an array-type probe.

[0008] Reference numerals in the drawings are as follows:

Best Modes for Carrying Out the Invention

[0009] From the viewpoint of inhibiting the brittle fracture of an electric resistance welded steel pipe for a line pipe with strength equal to or higher than that specified by the API X60 grade, the inventors have conducted studies on the distribution morphology of minute defects in a welded seam and a component system to achieve the toughness of the welded seam required and have found that the welded seam preferably has high toughness such that the absorbed energy at -40°C measured by a V-notch Charpy impact test is 100 J or more and that the high toughness is achieved by optimizing the area fraction of minute defects having a maximum length of less than 50 μm in the projection plane of the electric resistance welded seam and optimizing the chemical components (composition). Note that "the projection plane of the electric resistance welded seam" is used to indicate a plane when the region of a seam 2 shown in Fig. 1 is observed from the direction perpendicular to the seam face.

[0010] The area fraction of minute defects in the electric resistance welded seam and the chemical components of the electric resistance welded steel pipe according to the present invention will be described below.

[0011] The inventors have conducted intensive studies and have found that the amount of minute defects remaining in a weld seam of an electric resistance welded steel pipe participated in the toughness of the weld seam. As described above, penetrators in an electric resistance welded seam have been defined as oxides remaining on a welding face, each of the oxides being in the form of an ellipse having a size of 0.2 to 0.5 mm. The term "minute defects" in the present invention is used to indicate not defects having such a size but oxides, nitrides, or carbides having a maximum length of less than 50 μm.

[0012] The inventors have determined the relationship between the morphology of the minute defects and the toughness by an experiment using a seam-sliced-material C-scan method (abbreviated as C-scan method).

[0013] In this experiment, as shown in Fig. 1, a weld sample 3 was first obtained by slicing the electric resistance
welded steel pipe 1 at positions apart from the seam 2 of an electric resistance welded steel pipe 1 by a predetermined distance (in this case, 8 mm). To detect defects, the seam of the sample 3 was subjected to a C scan (along a scanning direction 5) with a convergence-type ultrasonic probe 4, and the signal intensity was measured.

Here, welding conditions of the electric resistance welded steel pipe as an experimental material include the normal condition of electric resistance welding; and the condition that the welding heat input and the upset value are adjusted so as to minimize the amount of minute defects. Various welding conditions were used. The convergence-type ultrasonic probe had a frequency of 20 MHz and a beam diameter of 440 \( \mu \text{m} \). Flaw detection was performed after the sensitivity was adjusted in such a manner that the echo height from a flat-bottomed hole having a diameter of 125 \( \mu \text{m} \) was 100%. The relationship between the signal intensity (echo height) and the defect size at the sensitivity setting is shown in Fig. 2. The term "defect size" is used to indicate a defect size (equivalent defect size) corresponding to the sum of the areas of minute defects each having a maximum length of less than 50 \( \mu \text{m} \) in the beam.

A Charpy specimen was taken from the C-scanned portion and subjected to the Charpy test to measure absorbed energy at -40°C (abbreviated as "-40°C absorbed energy"), determining the relationship between the absorbed energy and the signal intensity. Fig. 3 shows the results.

Fig. 3 shows that the echo height measured by the C scan correlates with the -40°C absorbed energy. When the echo heights were 27% or less, 40% or less, and 51% or less, the -40°C absorbed energy were 400 J or more, 200 J or more, and 20 J or more, respectively. Meanwhile, from Fig. 2, the echo heights of 27%, 40%, and 51% correspond to the presence of defects with a diameter of 63 \( \mu \text{m} \), 73 \( \mu \text{m} \), and 90 \( \mu \text{m} \), respectively. In view of a beam diameter of 440 \( \mu \text{m} \), the minute defect densities at the -40°C absorbed energy levels are shown in Table 1.

<table>
<thead>
<tr>
<th>Absorbed energy at-40°C</th>
<th>Echo height</th>
<th>Equivalent defect size</th>
<th>Equivalent defect area</th>
<th>Beam diameter Beam area</th>
<th>Minute defect density (per mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 J</td>
<td>27%</td>
<td>63 ( \mu \text{m} )</td>
<td>3117 ( \mu \text{m}^2 )</td>
<td>440 ( \mu \text{m} )</td>
<td>0.0205 mm(^2)</td>
</tr>
<tr>
<td>200 J</td>
<td>40%</td>
<td>78 ( \mu \text{m} )</td>
<td>4778 ( \mu \text{m}^2 )</td>
<td>440 ( \mu \text{m} )</td>
<td>0.0314 mm(^2)</td>
</tr>
<tr>
<td>20 J</td>
<td>51%</td>
<td>90 ( \mu \text{m} )</td>
<td>6362 ( \mu \text{m}^2 )</td>
<td>0.152 mm(^2)</td>
<td>0.0418 mm(^2)</td>
</tr>
</tbody>
</table>

Fig. 4 summarizes the experimental results. The results demonstrate that in the case where the minute defect density is 0.035 mm\(^2\) or less per 1 mm\(^2\) (i.e., the area fraction of minute defects is 0.035 or less), a -40°C absorbed energy of 100 J or more is obtained.

The lower limit of the area fraction of minute defects was set to 0.000006 (0.000006 mm\(^2\) per 1 mm\(^2\)) on the basis of the minimum density of oxides contained in industrially produced cleanliness steel.

The results of the investigation of the sliced seam sample by the C scan have been described above. Similar measurement of a steel pipe without processing can also be made by tandem inspection with a beam converging to an appropriate area. To allow the beam to converge, the same convergence-type ultrasound probe as that used in the C-scan may be used. Alternatively, for example, as shown in Fig. 5, an array-type probe 6 arranged in the circumferential direction may be used. In this case, an excessively small size of a beam results in difficulty in evaluating the area fraction of minute defects. An excessively large size of the beam leads to increased susceptibility to noise from internal and external surfaces of the pipe. Thus, the beam suitably has a diameter of 0.5 to 2.5 mm. In Fig. 5, the beam can be readily scanned in the thickness direction by electronically switching the positions of sending and receiving oscillators.

To achieve an area fraction of minute defects in the weld seam of 0.035 or less, the heat input control during electric resistance welding is necessary, but it is effective to perform the forming processing of edges of a plate in the width direction by, for example, proper cutting or rolling (preferably, fin-pass forming) before bending in the width direction by roll forming or in the course of the bending in such a manner that edge faces to be butted immediately before electric resistance welding each have a groove shape with a parallel facing portion located in the central region in the thickness direction and angled facing portions located on both sides of the parallel facing portion.

Preferred chemical components (composition) of the electric resistance welded steel pipe of the present invention will be described below. The composition of the electric resistance welded steel pipe is determined in view of a reduction in total cost when the pipe is laid. In particular, the composition is determined in view of requests by customers who place importance on a reduction in the transportation cost of steel pipes. Thus, a preferred composition range is specified in such a manner that a high strength equal to or higher than that specified by the API X60 grade is achieved. Note that the units of component contents in the composition are percent by mass and are simply indicated by %.

C: The C content is set in the range of 0.01% to 0.15%. C is an element that is precipitated as carbide and contributes to an increase in strength. A C content of less than 0.02% does not ensure sufficient strength. A C content exceeding 0.15% results in an increase in the fraction of a second phase, e.g., pearlite, bainite, or martensite, leading
to difficulty in ensuring material toughness required for a line pipe. Thus, the C content is set to 0.15% or less and preferably 0.07% or less. A C content of less than 0.01% results in difficulty in ensuring strength sufficient for a line pipe. Thus, the C content is preferably set to 0.01% or more.

[0023] Si: The Si content is set in the range of 0.005% to 0.9%. Si is added for deoxidation purposes. A Si content of less than 0.005% does not result in a sufficient deoxidation effect. A Si content exceeding 0.9% results in an increase in the number of oxides in the electric resistance welded seam, reducing the properties of the weld seam. Thus, the Si content is set in the range of 0.005% to 0.9%.

[0024] Mn: The Mn content is in the range of 0.2% to 2.0%. Mn is added to ensure strength and toughness. A Mn content of less than 0.2% does not result in a sufficient effect. A Mn content exceeding 2.0% results in an increase in the fraction of the second phase, leading to difficulty in ensuring excellent material toughness required for a line pipe. Thus, the Mn content is set in the range of 0.2% to 2.0%.

[0025] P: The P content is set to 0.01% or less. P is an incidental impurity that reduces weldability by electric resistance welding. Thus, the upper limit is set to 0.01%.

[0026] S: The S content is set to 0.01% or less. In general, S forms MnS inclusions in steel and acts as a starting point of hydrogen-induced cracking (HIC). Thus, the S content is preferably minimized. However, a S content of 0.01% or less does not cause a problem. Thus, the upper limit of the S content is set to 0.01%.

[0027] Al: The Al content is set to 0.1% or less. Al is added as a deoxidizer. An Al content exceeding 0.1% results in a reduction in the cleanliness of steel, reducing the toughness. Thus, the Al content is set to 0.1% or less.

[0028] In the present invention, to further improve the strength, yield ratio, and toughness of the electric resistance welded steel pipe for a line pipe, in addition to the foregoing components, the electric resistance welded steel pipe may further contain one or two elements selected from Cu (0.5% or less) and Ni (0.5% or less), one or two elements selected from Cr (3.0% or less) and Mo (2.0% or less), one or two or more elements selected from Nb (0.1% or less), V (0.1% or less), and Ti (0.1% or less), and Ca (0.005% or less).

[0029] Cu: The Cu content is set to 0.5% or less. Cu is an element effective in improving toughness and increasing strength. The addition of a large amount of Cu reduces the weldability. Thus, in the case of adding Cu, the upper limit of the Cu content is set to 0.5%.

[0030] Ni: The Ni content is set to 0.5% or less. Ni is an element effective in improving toughness and increasing strength. The addition of a large amount of Ni facilitates the formation of the hard second phase, leading to a reduction in the toughness of the material. Thus, in the case of adding Ni, the upper limit of the Ni content is set to 0.5%.

[0031] Cr: The Cr content is set to 3.0% or less. Like Mn, Cr is an element effective in providing a sufficient strength even at a low C content. The addition of a large amount of Cr facilitates the formation of the second phase, reducing the toughness of the material. Thus, in the case of adding Cr, the upper limit of the Cr content is set to 3.0%.

[0032] Mo: The Mo content is set to 2.0% or less. Like Mn and Cr, Mo is an element effective in providing a sufficient strength even at a low C content. The addition of a large amount of Mo facilitates the formation of the second phase, reducing the toughness of the material. Thus, in the case of adding Mo, the upper limit of the Mo content is set to 2.0%.

[0033] Nb: The Nb content is set to 0.1% or less. Nb improves strength and toughness by the fine precipitation of a carbonitride and the formation of finer grains in the structure. However, at a Nb content exceeding 0.1%, the hard second phase is readily increased, significantly reducing the toughness of the material. Thus, the Nb content is set to 0.1% or less.

[0034] V: The V content is set to 0.1% or less. Like Nb, V contributes to an increase in strength by the fine precipitation of a carbonitride. However, at a V content exceeding 0.1%, like Nb, the hard second phase is increased, significantly reducing the toughness of the material. Thus, the V content is set to 0.1% or less.

[0035] Ti: The Ti content is set to 0.1% or less. Like Nb and V, Ti contributes to an increase in strength by the fine precipitation of a carbonitride. However, at a Ti content exceeding 0.1%, like Nb, the hard second phase is increased, significantly reducing the toughness of the material. Thus, the Ti content is set to 0.1% or less.

[0036] Ca: The Ca content is set to 0.005% or less. Ca is an element needed to control the morphology of extended MnS that tends to act as a starting point of hydrogen-induced cracking. However, a Ca content exceeding 0.005% results in the formation of an excess of oxides and sulfides of Ca, leading to a reduction in toughness. Thus, the Ca content is set to 0.005% or less.

[0037] The balance other than the foregoing components is substantially Fe. The fact that the balance is substantially Fe indicates that steel containing incidental impurities and other trace elements may be included in the present invention unless the effect of the present invention is eliminated.

EXAMPLES

[0038] Steel samples (steel samples 1 to 10) having plate thicknesses and chemical compositions shown in Table 2 were used. Electric resistance welding was performed under two conditions: a conventional electric resistance welding condition (condition A) and an electric resistance welding condition (condition B) in which the processing of inner and outer surface side portions of edges by fin-pass forming before electric resistance welding in such a manner that the
edges have groove shapes makes it difficult to allow minute defects to remain in the weld seam, thereby producing an X65-grade electric resistance welded steel pipe with an external diameter of 20 inches.
<table>
<thead>
<tr>
<th>Steel sample</th>
<th>Chemical composition (mass%)</th>
<th>Plate thickness (mm)</th>
<th>Preferred composition range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>Si</td>
<td>Mn</td>
</tr>
<tr>
<td>1</td>
<td>0.19</td>
<td>0.55</td>
<td>1.55</td>
</tr>
<tr>
<td>2</td>
<td>0.08</td>
<td>0.25</td>
<td>2.51</td>
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<tr>
<td>3</td>
<td>0.07</td>
<td>0.21</td>
<td>1.37</td>
</tr>
<tr>
<td>4</td>
<td>0.02</td>
<td>0.19</td>
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<td>0.19</td>
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<td>7</td>
<td>0.04</td>
<td>0.21</td>
<td>1.21</td>
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<td>10</td>
<td>0.16</td>
<td>0.55</td>
<td>1.55</td>
</tr>
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</table>
Any of the steel samples were subjected to hot rolling to have a predetermined thickness and then coiled to form a hot-rolled coil. Table 3 shows the toughness of the base material, the toughness of the weld seam, and the area fraction of minute defects in the weld seam. With respect to the toughness of the base material, ten JIS No. 5 2-mm V-notch Charpy impact test specimens were taken from a position 180° apart from the electric resistance welded seam of each steel sample in the circumferential direction. With respect to the toughness of the weld seam, ten JIS No. 5 2-mm V-notch Charpy impact test specimens were taken from the electric resistance welded seam of each steel sample. Then -40°C absorbed energy was measured. In view of manufacturing variations, evaluation criteria were as follows.

**Excellent:** The -40°C absorbed energy of the weld seam is 125 J or more. In this case, target properties are sufficiently satisfied.

**Acceptable:** The -40°C absorbed energy of the weld seam is 100 J or more and less than 125 J. In this case, the target properties are not sufficiently satisfied but are satisfied at an acceptable level.

The area fraction of minute defects in the weld seam was measured by array ultrasonic testing shown in Fig. 5.
<table>
<thead>
<tr>
<th>No.</th>
<th>Steel sample</th>
<th>Welding condition</th>
<th>-40°C absorbed energy (J)</th>
<th>Minimum</th>
<th>Mean</th>
<th>Evaluation</th>
<th>Maximum</th>
<th>Evaluation</th>
<th>Comprehensive evaluation</th>
<th>Remark</th>
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<td>No.</td>
<td>Steel sample</td>
<td>Welding condition</td>
<td>–40°C absorbed energy (J)</td>
<td>Comprehensive evaluation</td>
<td>Remark</td>
<td>Comparative Example</td>
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<tr>
<td>17</td>
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In steel sample 1 in which the C and S contents were greatly outside the preferred range, the structure was a ferrite-bainite system. The base material had low toughness. Also in the case of any of the electric resistance welding conditions A and B, the weld seam had low toughness. In steel samples 2 and 3 in which the Mn or Nb content was greatly outside the preferred range, the base material had sufficient toughness. In the case of any of the welding conditions, however, the toughness of the weld seam was low and did not satisfy a -40°C absorbed energy of 100 J or more. In steel samples 4 to 9 in which the compositions were inside the preferred range, in the case of the conventional electric resistance welding (condition A), there were specimens having an area fraction of minute defects in the weld seam exceeding 0.035 and a -40°C absorbed energy of less than 100 J. In contrast, in the case of the electric resistance welding (condition B) that made it difficult to allow minute defects to remain, in each specimen, the area fraction of minute defects in the weld seam was 0.035 or less, and high -40°C absorbed energy was stably exhibited. In steel sample 10 in which the C content was slightly outside the preferred range, in the case of the electric resistance welding under the condition B, the area fraction of minute defects in the weld seam was 0.035 or less, and the -40°C absorbed energy of the weld seam was 100 J or more and less than 125 J.

Claims

1. An electric resistance welded steel pipe with excellent weld toughness for a line pipe, wherein the electric resistance welded steel pipe consists of a percent by mass basis, 0.01% to 0.15% C, 0.005% to 0.9% Si, 0.2% to 2.0% Mn, 0.01% or less P, 0.01% or less S, 0.1% or less Al, and optionally one or two selected from 0.5% or less Cu and 0.5% or less Ni, and/or one or two selected from 3.0% or less Cr and 2.0% or less Mo, and/or one or two selected from 0.1% or less Nb, 0.1% or less V, and/or 0.005% or less Ca and the balance being Fe; wherein an absorbed energy at -40°C measured in an impact test for metallic materials (V-notch Charpy test specimen) according to ISO 148 (JIS Z 2242) on a specimen of the steel pipe, in which a V-notch according to ISO/DIS 148-1 (JIS Z 2202) is formed on the electric resistance welded seam of the specimen for the impact test for metallic materials, is 100 J or more; wherein the steel pipe has in a projection plane of the electric resistance welded seam (2) an area fraction of minute defects in the range of 0.000006 to 0.035, each minute defect has a maximum length of less than 50 µm.

2. The electric resistance welded steel pipe with excellent weld toughness for a line pipe according to Claim 1, wherein the minute defects are composed of one or two or more selected from oxides, nitrides, and carbides remaining in a weld face when electric resistance welding is performed.

Patentansprüche

1. Widerstandsgeschweißtes Stahlrohr mit ausgezeichneter Verschweißungsfestigkeit für eine Rohrleitung, wobei das widerstandsgeschweißte Stahlrohr aus 0,1 Gew% bis 0,15 Gew% C, 0,005 Gew% bis 0,9 Gew% Si, 0,2 Gew% bis 2,0 Gew% Mn, 0,01 Gew% oder weniger P, 0,01 Gew% oder weniger S, 0,1 Gew% oder weniger Al und optional einem oder zwei Bestandteil/en, der/die aus 0,5 Gew% oder weniger Cu und 0,5 Gew% oder weniger Ni ausgewählt wird/werden, und/oder einem oder zwei Bestandteil/en, der/die aus 3,0 Gew% oder weniger Cr und 2,0 Gew% oder weniger Mo ausgewählt wird/werden, und/oder einem oder zwei oder mehr Bestandteil/en, der/die aus 0,1 Gew% oder weniger Nb, 0,1 Gew% oder weniger V sowie 0,005 Gew% oder weniger Ti ausgewählt wird/werden, und/oder 0,005 Gew% oder weniger Ca besteht, wobei der Rest Fe ist; eine absorbierte Energie bei -40°C gemessen bei einem Schlagversuch für Metallmaterialien (Charpy-Spitzkerb-Muster) gemäß ISO 148 (JIS Z 2242) an einem Muster des Stahlrohrs, bei dem eine Spitzkerbe gemäß ISO/DIS 148-1 (JIS Z 2202) an der Widerstands-Schweißnaht des Musters für den Schlagversuch für Metallmaterialien erzeugt wird, 100 J oder mehr beträgt; das Stahlrohr in einer Projektionsebene der Widerstands-Schweißnaht (2) einen Flächenanteil an kleinsten Defekten im Bereich von 0,000006 bis 0,035 hat, wobei jeder kleinste Defekt eine maximale Länge von weniger als 50 µm hat.

2. Widerstandsgeschweißtes Stahlrohr mit ausgezeichneter Verschweißungsfestigkeit für eine Rohrleitung nach Anspruch 1, wobei die kleinsten Defekte aus einem oder zwei oder mehr Defekt/en bestehen, der/die aus Oxiden, Nitriden und Karbiden ausgewählt wird/werden, die an einer Schweißnaht-Oberfläche verbleiben, wenn WiderstandsSchweißen durchgeführt wird.
Revendications

1. Tuyau en acier soudé par résistance électrique présentant une excellente résistance des parties soudées destiné à un tube de canalisation, le tube d’acier soudé par résistance électrique consistant, sur la base d’un pourcentage en masse, en 0,01 % à 0,15 % de C, 0,005 % à 0,9 % de Si, 0,2 % à 2,0 % de Mn, 0,01 % ou moins de P, 0,01 % ou moins de S, 0,1 % ou moins de Al et, en option, en un ou deux sélectionnés parmi 0,5 % ou moins de Cu et 0,5 % ou moins de Ni, et/ou en un ou deux sélectionnés parmi 3,0 % ou moins de Cr et 2,0 % ou moins de Mo, et/ou en un ou deux ou plus sélectionnés parmi 0,1 % ou moins de Nb, 0,1 % ou moins de V et 0,1 % ou moins de Ti, et/ou en 0,005 % ou moins de Ce, l’équilibre étant représenté par Fe,
dans lequel l’énergie absorbée à -40 °C, mesurée lors d’un test d’impact pour matériaux métalliques (spécimen de test de type Charpy sur encoche en V) conforme à la norme ISO 148 (JIS Z 2242) sur un spécimen de tuyau en acier dans lequel une encoche en V conforme à la norme ISO/DIS 148-1 (JIS Z 2202) est formée sur le cordon de soudure par résistance électrique du spécimen pour le test d’impact pour matériaux métalliques, est égale à 100 J ou plus,
dans lequel le tuyau en acier présente, en plan de projection du cordon de soudure par résistance électrique (2), une fraction de surface de défauts minimes dans la plage allant de 0,000006 à 0,035, chaque défaut minime présente une longueur maximale inférieure à 50 μm.

2. Tuyau en acier soudé par résistance électrique présentant une excellente résistance des parties soudées destiné à un tube de canalisation selon la revendication 1, dans lequel les défauts minimes sont composés d’un ou deux ou plus sélectionnés à partir d’oxydes, de nitrures et de carbures restant sur la face soudée lorsque le soudage par résistance électrique est exécuté.
FIG. 4

![Graph showing absorbed energy at -40°C versus density of minute penetrator per 1 mm² (mm²).]

FIG. 5

![Diagram illustrating sending and receiving directions with labeled parts 1, 2, 6.]

116 625 B1
REFERENCES CITED IN THE DESCRIPTION

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