Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2885696 C 2021/04/20

(11)(21) **2 885 696**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 2013/09/26
(87) Date publication PCT/PCT Publication Date: 2014/04/03
(45) Date de délivrance/Issue Date: 2021/04/20
(85) Entrée phase nationale/National Entry: 2015/03/20
(86) N° demande PCT/PCT Application No.: CN 2013/084267
(87) N° publication PCT/PCT Publication No.: 2014/048337
(30) Priorité/Priority: 2012/09/29 (CN201210378301.9)

(51) Cl.Int./Int.Cl. *C22C 38/50* (2006.01), *C21D 9/08* (2006.01), *C21D 9/50* (2006.01), *C22C 38/02* (2006.01), *C22C 38/04* (2006.01), *C22C 38/06* (2006.01), *C22C 38/42* (2006.01), *C22C 38/44* (2006.01), *C22C 38/46* (2006.01), *C22C 38/48* (2006.01)

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(54) Title: HIGH-FREQUENCY STRAIGHT WELDED PIPE AND MANUFACTURING METHOD THEREOF

(57) Abrégé/Abstract:
The present invention discloses a high-frequency straight welded pipe. The high-frequency straight welded pipe comprises the following chemical element percentages by mass: 0.042-0.056% of C, 0.18-0.22% of Si, 0.75-0.95% of Mn, 0.0064-0.015% of P, 0.0006-0.002% of S, 0.012-0.018% of Ti, 0.001-0.002% of V, 0.026-0.038% of Al, 0.080-0.13% of Ni, 0.020-0.029% of Nb, 0.125-0.135% of Cu, 0.018-0.03% of Cr, 0.004-0.008% of Mo, 0-0.0005% of B, 0.001-0.003% of Ca, and the balance of Fe and other inevitable impurities. Meanwhile, further disclosed is a manufacturing method for the high-frequency straight welded pipe.

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ABSTRACT

The present invention discloses a high-frequency straight welded pipe. The high-frequency straight welded pipe comprises the following chemical elements percentages by mass: 0.042-0.056% of C, 0.18-0.22% of Si, 0.75-0.95% of Mn, 0.0064-0.015% of P, 0.0006-0.002% of S, 0.012-0.018% of Ti, 0.001-0.002% of V, 0.026-0.038% of Al, 0.080-0.13% of Ni, 0.020-0.029% of Nb, 0.125-0.135% of Cu, 0.018-0.03% of Cr, 0.004-0.008% of Mo, 0-0.0005% of B, 0.001-0.003% of Ca, and the balance of Fe and other inevitable impurities. Meanwhile, further disclosed is a manufacturing method for the high- frequency straight welded pipe.

High-Frequency Straight Welded Pipe and Manufacturing Method Thereof

Technical Field

The invention relates to a steel pipe and a method for manufacturing the same, particularly to a high frequency welded pipe and a method for manufacturing the same.

Background Art

In the field of production and transportation of petroleum and natural gas, high frequency straight welded pipes (HFW) are used widely owing to their advantages of low manufacture cost, high dimension precision, easy control over specified lengths, etc. They are employed mainly for transportation of petroleum, natural gas, ore slurry on the land and under the sea, and have a broad prospect in application.

Along with the ever growing global demand on petroleum and natural gas, the exploitation conditions in petroleum and natural gas wells tend to be worse and more complicated. As oil and gas fields characterized by badly corrosive environment with high contents of H and S are developed successively, it is urgent for steel pipe manufacturers to develop and produce pipes suitable for transporting petroleum and natural gas under this kind of acidic operation condition. At present, there are more than one hundred sets of high frequency straight welded pipe (HFW) machines in China. However, most manufacturers have to purchase plate volumes from large steel makers that mainly produce steel pipes of conventional steel grades. No domestic plant produces HIC (hydrogen induced crack) resistant pipeline pipes of higher steel grades having superior properties that are needed raringly in the market. Up to now, there still remains a domestic blank area for HIC-resistant high-frequency straight welded pipes of grade L360MCS and a process of manufacturing the same.

Summary

The object of the invention is to provide a high frequency straight welded pipe and a method for manufacturing the same, wherein the high frequency straight welded pipe possesses good HIC resistance, properties of steel grade L360MCS, high yield strength, high tensile strength, high impact toughness and good weldability.

In order to achieve the above object of the invention, there is provided a high frequency straight welded pipe, comprising the following chemical elements in mass percentages

C: 0.042-0.056%;

Si: 0.18-0.22%;

Mn: 0.75-0.95%;

P: 0.0064-0.015%;

S: 0.0006-0.002%;

Ti: 0.012-0.018%;

V: 0.001-0.002%;

Al: 0.026-0.038%;

Ni: 0.080-0.13%;

Nb: 0.020-0.029%;

Cu: 0.125-0.135%;

Cr: 0.018-0.03%;

Mo: 0.004-0.008%;

B: 0-0.0005%;

Ca: 0.001-0.003%;

the balance of Fe and other unavoidable impurities.

The main chemical elements in the high frequency straight welded pipe of the invention are designed according to the following principles:

C: Carbon is the main solid solution strengthening element in the pipeline pipe. A good number of experiments conducted by the researchers demonstrate that the sensitivity of strip steel to hydrogen induced crack (HIC) increases as the carbon content in the strip steel increases. Thus, it is necessary to control the carbon content appropriately to an acceptable low range that will not affect the strength of the strip steel. The carbon content in the composition of the invention is reduced suitably, from about 0.07wt% which is generally used in the prior art to not more than 0.056wt%. As such, the carbon in the technical solution of the invention is controlled in the range of 0.042-0.056wt%.

S: In low sulfur steel, the crack length ratio is reduced and MnS appears at the fracture face, indicating that the generation of cracks may be controlled effectively by reduction of N, S in strip steel. Nevertheless, it is unnecessary to seek reduction of the sulfur content blindly because cracks in the strip steel cannot be avoided completely even if the sulfur content is reduced to an extremely low level. The inventors have carried out a lot of experiments and found that, when the mass percentage of sulfur is controlled in the range of 0.0006-0.002%, not only the requirement of corrosion resistance can be fulfilled, but also cracking in the strip steel can be prevented.

Ca: Calcium treatment has an important influence on the hydrogen induced crack (HIC) resistance of strip steel. In the technical solution of the invention, a suitable amount of calcium is added into the composition. CaS precipitated at the final solidification position is converted into spherical inclusions after rolling, so that the hydrogen induced crack (HIC) resistance of the strip steel is improved. Yet, control over the calcium content is related with the sulfur content. Hence, the calcium content in the technical solution of the invention is controlled in the range of 0.001-0.003wt%.

Cu: Among the variety of alloy elements, copper is the only element that is beneficial to the hydrogen induced crack (HIC) resistance. When an amount of copper is added into pipeline steel, the sensitivity to hydrogen induced crack is decreased remarkably. The main reason is that copper facilitates the formation of a passivation film which blocks invasion of hydrogen element and thus inhibits formation of hydrogen induced crack. According to the technical solution of the invention, an amount of copper is added to improve the hydrogen induced crack (HIC) resistance. Therefore, the copper content is controlled in the range of 0.125-0.135wt%.

Mn: The effect of manganese on the sensitivity of pipeline steel to hydrogen induced crack principally resides in the influence of manganese on the phase transition of the strip steel. If the manganese content exceeds 1.0wt%, the sensitivity to hydrogen induced crack (HIC) increases. Therefore, the manganese content in the technical solution of the invention is controlled in the range of 0.75-0.95wt%.

Accordingly, the invention also provides a method for manufacturing the above high frequency straight welded pipe, comprising the following steps:

in a shell forming step, the squeeze is controlled in the range of 2-3% of the outer diameter of the welded pipe;

in a welding step, the welding speed is controlled in the range of 18-20m/min;

in a post-welding heat treatment step, the welding line is normalized at 930-970°C, followed by air cooling to below 380°C and water cooling to below 80°C.

Further, in the shell forming step of the method for manufacturing a high frequency straight welded pipe according to the invention, the opening angle is controlled in the range of 3-4.2°.

In the technical solution of the invention, the squeeze measured before and after welding is controlled in the range of 2-3% of the outer diameter of the welded pipe, wherein the squeeze refers to the difference between the perimeter of the shell before squeezing and the perimeter after the squeezing. In a molten state, the molten pool at the welding line is exposed to air and susceptible to oxidation, wherein the product of the oxidation reaction is closely related with the chemical composition of the strip steel. Hence, a relatively large squeeze needs to be applied to squeeze the resulting product with high melting point to the surface of the welding line on the strip steel and remove the same by deburring. If the squeeze is lower than 2%, flaws such as cold welding will occur, such that the inclusions in the strip steel cannot be expelled to the surface of the welding line for removal, and the quality of the strip steel will be affected.

The welding speed is set in the range of 18-20m/min for the reason that the welding speed is generally inversely proportional to the welding power, such that a rapid welding speed tends to counteract the expellability of the inclusions resulted from a high welding power and a large squeeze, leading to decreased effect in expelling the inclusions. Therefore, the inventors control the welding speed in the range of 18-20m/min according to the technical solution of the invention.

According to the method for manufacturing a high frequency straight welded pipe in the invention, on the basis of the utilization of a manufacturing method of high frequency straight induction welding (HFW), a high frequency straight welded pipe that meets the requirements of HIC resistance, tensile property, impact toughness and microstructure is manufactured by reasonably regulating the squeeze and the forming process, setting the high frequency weld forming and welding parameters, and controlling the technical parameters of the subsequent heat treatment.

Compared with the prior art, the high frequency straight welded pipe of the invention has good HIC resistance, properties of steel grade L360MCS, high yield strength, high tensile strength, high impact toughness and good weldability, and is suitable for use as a transporting pipe in a harsh operation environment where the contents of H and S are high or acidic corrosion exists.

Detailed Description of the Invention

Examples 1-6

The high frequency straight welded pipe of the invention was manufactured in accordance with the following steps:

The head and tail portions of unrolled steel rolls were cut off, and cuts were formed flush at an angle of 3° relative to the traverse direction of the steel rolls. The tail of a preceding steel roll was welded to the head of a succeeding steel roll by carbon dioxide shielded welding. The steel strip was used to manufacture a high frequency straight welded pipe, wherein the edge of the plate was treated by edge milling to control the width of the steel strip and the plumbness of the plate edge precisely. The steel strip was formed into a shell by a cage roll forming process. The squeeze was controlled in the range of 2-3% of the outer diameter of the welded pipe, and the opening angle was controlled in the range of 3-4.2°. The welding speed was controlled in the range of 18-20m/min during welding. After welding, the welding line was normalized at 930-970°C, followed by air cooling to below 380°C and water cooling to below 80°C. The wall thickness of the high frequency straight welded pipe obtained by the above process was 6.4mm-9.5mm, and the pipe diameter was 219.7mm-406.4mm.

Table 1 lists the chemical compositions of the high frequency straight welded pipes of Examples 1-6.

Table 1 (The balance is Fe and other unavoidable impurities, wt%)

Ex.	1	2	3	4	5	6
C	0.0551	0.0553	0.0499	0.0494	0.0517	0.0421
Si	0.18	0.182	0.0182	0.182	0.183	0.22
Mn	0.886	0.886	0.0878	0.877	0.750	0.950
P	0.0136	0.0136	0.0118	0.0121	0.0064	0.0149
S	0.002	0.0012	0.0014	0.0015	0.0006	0.0010
Ti	0.014	0.014	0.014	0.014	0.012	0.018
V	0.001	0.001	0.001	0.001	0.002	0.001
Al	0.031	0.026	0.030	0.030	0.028	0.038
Ni	0.096	0.096	0.096	0.096	0.08	0.128
Nb	0.027	0.027	0.026	0.027	0.020	0.029
Cu	0.132	0.129	0.13	0.129	0.125	0.135
Cr	0.026	0.026	0.026	0.027	0.030	0.018
Mo	0.005	0.005	0.005	0.005	0.004	0.008
B	0.0001	0.0002	0.0002	0.0002	0	0.0005
Ca	0.0018	0.0020	0.0020	0.0023	0.0029	0.0010

Table 2 lists the detailed process parameters for manufacturing the high frequency straight welded pipes of Examples 1-6.

Table 2

Ex.	Squeeze (%)	Welding Speed (m/min)	Opening Angle (°)	Normalizing Temperature (°C)	Air Cooling Temperature for the Welding Line(°C)	Water Cooling Temperature for the Welding Line (°C)	Strip Width After Milling (mm)	Output Power (KW)	Wall Thickness of Welded Pipe (mm)	Diameter of Welded Pipe (mm)
1	2.9	20	3.8	950	360	42	700	450	6.4	219.7
2	2	18	4	955	365	46	1285	840	8.7	406.4
3	2.7	18	4	960	370	50	1281	906	9.5	406.4
4	3	18	4	960	375	38	1024	772	9.1	323.9

5	2.62	20	3.8	950	350	35	1031	572	6.4	323.9
6	2.46	18	4	955	360	40	1289	698	7.1	406.4

Table 3 lists the performance parameters of the high frequency straight welded pipes of Examples 1-6.

Table 3

Ex.	Welded Pipe Body						Welding Line of Welded Pipe			Whole		
	Yield Strength (MPa)	Tensile Strength (MPa)	Elong-ation (%)	Yield Ratio	Impact Toughness/Charpy Impact Energy (J)		Tensile Strength (MPa)	Impact Toughness/Charpy Impact Energy (J)		Hydrogen Induced Crack (HIC) Resistance		
					Minimum	Average		Minimum	Average	Crack Sensitive Rate (CSR)	Crack Length Rate (CLR)	Crack Thickness Rate (CLR)
1	478	545	28	0.877	119	127	475	139	145	0	0	0
2	399	505	37	0.790	198	259	480	284	318	0	0	0
3	422	520	37	0.812	293	301	487	266	268	0	0	0
4	455	540	24	0.843	231	241	510	225	239	0	0	0
5	400	510	34	0.784	170	180	490	160	166	0	0	0
6	420	520	24	0.808	150	162	505	202	214	0	0	0

As shown by Table 3, the high frequency straight welded pipe of the invention possesses superior mechanical properties and HIC resistance. Specifically, the welded pipe body exhibits a yield strength ≥399MPa, a tensile strength ≥505MPa, an elongation ≥24%, and the welding line of the welded pipe has a tensile strength ≥475MPa, indicating that the high frequency straight welded pipe as a whole meets the requirement of high strength and possesses high tensile capability. With respect to impact toughness, the Charpy impact energy of the welded pipe body has a minimum ≥119J and an average ≥127J, and that of the welding line of the welded pipe has a minimum ≥139J and an average ≥145J, indicating that the high frequency straight welded pipe has good toughness and weldability. The crack sensitive rate (CSR), the crack length rate (CLR) and the crack thickness rate (CTR), which are used for evaluating the hydrogen induced crack (HIC) resistance of a strip steel material, are all 0% as shown in Table 3, demonstrating the good hydrogen induced crack (HIC) resistance of the high frequency straight welded pipe.

It is to be noted that the above specific examples of the invention are only exemplary. Obviously, the invention is not limited to the above examples. Rather, a number of variations can be made. All variations derived directly or contemplated from the disclosure of the invention by one skilled in the art fall within the protection scope of the invention.

CLAIMS

What is claimed is:

1. A high frequency straight welded pipe, comprising the following chemical elements in mass percentages:

C: 0.042～0.056%;

Si: 0.18～0.22%;

Mn: 0.75～0.95%;

P: 0.0064～0.015%;

S 0.0006～0.002%;

Ti 0.012～0.018%;

V 0.001～0.002%;

Al 0.026～0.038%;

Ni 0.080～0.13%;

Nb 0.020～0.029%;

Cu 0.125～0.135%;

Cr 0.018～0.03%;

Mo 0.004～0.008%;

B 0～0.0005%;

Ca 0.001～0.003%;

the balance of Fe and other unavoidable impurities.

2. A method for manufacturing the high frequency straight welded pipe of claim 1, wherein:

in a shell forming step, the squeeze is controlled to be 2～3% of the outer diameter of the welded pipe;

in a welding step, the welding speed is controlled in the range of 18～20m/min;

in a post-welding heat treatment step, the welding line is normalized at 930～970°C, followed by air cooling to below 380°C and water cooling to below 80°C.

3. The method for manufacturing the high frequency straight welded pipe according to claim 2, wherein in the shell forming step, the opening angle is controlled in the range of 3～4.2°.