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(54) **USE OF A DUPLEX STAINLESS STEEL OBJECT**

VERWENDUNG EINES DUPLEXEDELSTAHLOBJEKTS

UTILISATION D'UN OBJET EN ACIER INOXYDABLE DUPLEX

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(56) References cited:

**JP-A- 2005 194 624 JP-A- 2012 140 689
JP-A- 2012 188 727 JP-A- 2014 136 813
JP-A- 2016 053 213**

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a use of an object made of a duplex (ferritic-austenitic) stainless steel in sea water applications wherein this object has a surprisingly good resistance against hydrogen induced stress corrosion (HISC).

BACKGROUND ART

10 **[0002]** Cathodic protection (CP) offshore for prevention of pitting corrosion of duplex and superduplex stainless steels used for subsea components on high temperature wells has been used for more than 20 years. Cathodic protection is defined as an electrochemical protection by decreasing the corrosion potential to a level at which the corrosion rate of the metal is significantly reduced. Thus, it is a technique to reduce corrosion of a metal surface by making that surface
15 the cathode of an electrochemical cell. Hence, the duplex stainless steel will be the cathode and another metal will be the anode (usually Zn).

[0003] Even though duplex stainless steels have been a very good choice of material to use in conjunction with cathodic protection, some failures have been encountered over the past years relating to hydrogen induced stress corrosion cracking, also known as HISC. HISC is a non-ductile mode of failure having its origin in a combination between stresses,
20 use of a cathodic protection system and use of a material with a susceptible microstructure and is caused by atomic hydrogen diffusion. This failure has an impact on the strength and the ductility of the duplex stainless steels as these materials due to HISC will become more prone to brittle cracking, especially during the application of high loads.

[0004] JP2012140689A and JP2016053213A disclose duplex stainless steels for seawater applications.

25 **[0005]** Hence, there exists still a need for further improvements of duplex (ferritic-austenitic) stainless steel used for manufacturing objects which are to be use in sea water applications, especially in applications where the duplex stainless steel will be used for cathodic protection (the duplex stainless steel will function as the cathode).

DETAILED DESCRIPTION

30 **[0006]** It is therefore an aspect of the present invention to provide an object made of a duplex (ferritic-austenitic) stainless steel which object is to be used in sea water applications. This duplex stainless steel object has an element composition which together with the manufacturing method will provide good resistance against hydrogen induced stress corrosion (HISC). The present invention is disclosed in the appended claims.

35 **[0007]** According to one embodiment, the use of the object comprises the use of the duplex stainless steel alloy as defined hereinabove or hereinafter in cathode protection, i.e. such as a cathode.

[0008] By the optimizing the element composition of the present duplex stainless steel and the process for manufacturing the object, the object comprising the duplex stainless steel will have a high corrosion resistance and good structure stability. Hence, the present duplex stainless steel has due to this complex optimization been found to combine several good properties, such as shown in the following disclosure.

40 **[0009]** Thus, the present invention provides an object of a duplex stainless steel, which object will have high corrosion resistance, high strength and toughness. Also, the object of the present invention is easy to manufacture and has good workability, which, for example enables extrusion into seamless tubes. Due to the its composition and its manufacturing process, the object will contain essentially no sigma phase (essentially no sigma phase is present). This is very advantageous as this means that the problems with corrosion, brittle fracture and nitride formation during welding are reduced
45 and/or eliminated.

[0010] The process for manufacturing the present object as defined hereinabove or hereinafter must contain a step of solution annealing. Solution annealing means that the object is heat treated in a temperature above the recrystallization temperature of the duplex stainless steel as defined hereinabove or hereinafter.

50 **[0011]** The alloying elements and their compositional ranges of the duplex stainless steel according to the present disclosure will now be further described.

[0012] **Carbon (C)**, is an impurity contained in duplex stainless steels. When the content of C exceeds 0.03 wt%, the corrosion resistance is reduced due to the precipitation of chromium carbide in the grain boundaries. Thus, the content of C is less than or equal to 0.03 wt%, such as less than or equal to 0.02 wt%.

55 **[0013]** **Silicon (Si)**, is an element which may be added for deoxidization. However, too much Si will promote the precipitation of intermetallic phases, such as sigma phase; therefore, the content of Si is 0.5 wt% or less.

[0014] **Manganese (Mn)**, is used in most duplex stainless steels at levels up to about 1.0 wt%.

[0015] One important reason is that Mn has the ability to bind sulphur, which is an impurity, into MnS, which is favorable to the hot ductility. Thus, in order to have this effect, the content of Mn is less than or equal to 1.0 wt%.

[0016] Nickel (Ni), is an austenite stabilizing element and needs to be present to achieve the desired phase balance between ferrite phase and austenite phase. Thus, the content of Ni is from 6.0 to 7.0 wt%.

[0017] Chromium (Cr), is the most important element in a duplex stainless steel as Cr is essential for creating the passive oxide film, which will protect the duplex stainless steel from corrosion. Also, the addition of Cr will increase the solubility of nitrogen (N). If the Cr content is too low, the pitting resistance is reduced. If the Cr content is too high, the resistance against HISC is reduced. As shown in Figure 1, a linear relation between the HISC- resistance and the equation $Cr + 50N$ has been found meaning that the resistance against HISC within the duplex stainless steel as defined hereinabove or hereinafter is related to the content of both Cr and N. As can be seen from figure 1, if the Cr and N are too high, then the resistance against HISC will be reduced. Accordingly, the content of Cr is from 23.0 to 24.0 wt%.

[0018] Molybdenum (Mo), is an effective element in stabilizing the passive oxide film formed on the surface of the duplex stainless steel and is also effective in improving the stress corrosion cracking-and pitting resistance. When the content of Mo is less than 2.5 wt%, then the stress corrosion cracking-and pitting resistance is not high enough. If the Mo content is too high, there will be a risk for the formation of intermetallic phases which will make the material brittle. Accordingly, the content of Mo is of from 2.5 to 4.5 wt%, such as of from 2.8 to 4.0 wt%.

[0019] Nitrogen (N), is an effective element for increasing the strength in duplex stainless steels by solution hardening. If the N content is too low, the mechanical properties and pitting resistance will be reduced. If the N is too high, the resistance against HISC will be reduced. As shown in Figure 1, a linear relation between the HISC- resistance and the equation $Cr + 50N$ has been found, Therefore, the content of N is of from 0.1 to 0.2 wt%, such as of from 0.12 to 0.20 wt%.

[0020] Phosphorus (P), is an impurity contained in the duplex stainless steel and it is well known that P will have a negative effect on the hot workability. Accordingly, the content of P is set at 0.03 wt% or less, such as 0.02 wt% or less.

[0021] Sulphur (S), is an impurity contained in the duplex stainless steel, and it will deteriorate the hot workability at low temperatures. Accordingly, the allowable content of S is less than or equal to 0.03 wt%, such as less than or equal to 0.02 wt%.

[0022] Copper (Cu), is an optional element which may or may not be included in the present duplex stainless steel depending on which scrap is used as a starting material for making the melt. Cu as such may stabilize the passive film formed on the surface of the duplex stainless steel and may in low concentration improve the pitting resistance and the corrosion resistance. Therefore, the allowable content of Cu is less than or equal to 0.3 wt%, such as less than or equal to 0.2 wt%.

[0023] Aluminum (Al), is a deoxidizing element and may be optionally contained in the present duplex stainless steel. If the Al content is more than 0.10 wt%, the formation of intermetallic phases, such as sigma phase, will be promoted. Also, if Al is added at levels above 0.10 wt%, AlN or NiAl may be formed which will have an effect on the mechanical properties. Therefore, in order to obtain a duplex stainless steel having the properties as described hereinabove or hereinafter, the Al content is less than or equal 0.10 wt%.

[0024] It has surprisingly been found that a solution-annealed object composed of duplex stainless steel as defined hereinabove or hereinafter and which fulfills the equation of $Cr+50N$ is less than or equal to 34 (see Figure 1) will have a better resistance against HISC, the amounts of Cr and N in this equation is in weight%. This means that the content of Cr is connected to the content of N meaning that the content of Cr and N in the hereinabove or hereinafter defined duplex stainless steel is found to be low (if compared to other known duplex stainless steels). It should be noted that according to the common general knowledge that a relation between Cr to N could not have been predicted because the susceptibility for HISC has earlier been attributed to the microstructure of the duplex stainless steel and not the chemical composition of the duplex stainless steel. It can further be noted that duplex grades commonly used for these applications have a content of 25 wt% Cr and more than 0,25 wt% N. According to the invention, $Cr+50N$ is less than or equal to 34, such less than or equal to 33.

[0025] According to the present invention, the process for manufacturing an object comprising of the duplex stainless steel as defined hereinabove or hereinafter must comprise a step of solution annealing before being used in sea water applications. Solution annealing means that the object is heat treated and this step will improve the microstructure of the duplex stainless steel whereby the ductility and toughness will be increased. The solution annealing should be performed at temperatures above the recrystallisation temperature of the duplex stainless steel. According to one embodiment, the solution annealing

[0026] temperature is in the range of from 1030 to 1150°C. According to one embodiment, the solution annealing is followed by rapid cooling in air or in water. The solution annealing is performed after a cold working step, such as cold deformation, such as squeezing, bending, shearing, pilgering or drawing.

[0027] The microstructure of a duplex stainless steel is a two-phased structure comprising austenite islands embedded in a ferritic matrix. The more closely packed austenite phase (FCC) has larger voids in the structure than the ferritic BCC structure. This structure will have implications for hydrogen diffusion and the hydrogen solubility. The diffusion rate of hydrogen is much faster in the ferrite phase compared to austenite phase, while the solubility of hydrogen is higher in austenite phase than the ferrite phase. It has been shown that cracks due to HISC often start in the ferrite phase and that the austenite phase in many cases will act as a crack inhibitor. Hence, in the present invention, the distribution of the

two phases is balanced in the object in order to provide approximately equal amounts of ferrite phase and austenite phase in the solution-annealed condition. Accordingly, the ferrite phase content of object is in the range of from 40% to 60 % by volume, such as in the range of from 45% to 55% by volume, balanced by the austenite phase.

[0028] Other elements may optionally be added to the duplex stainless steel as defined hereinabove or hereinafter for example during the manufacturing process in order to improve for example the processability, such as the hot workability, the machinability etc.

[0029] Such elements are Titanium (Ti), Calcium (Ca), Cerium (Ce) and Boron (B). If added, these elements are in an amount of max 0.5 wt% in total. According to one embodiment, the duplex stainless steel according to the present disclosure consist of all the elements as defined hereinabove or hereinafter in the ranges as defined hereinabove or hereinafter.

[0030] The balance in the duplex stainless steel is Iron (Fe) and unavoidable impurities. Examples of unavoidable impurities are elements and compounds which have not been added on purpose, but cannot be fully avoided as they normally occur as impurities in e.g. the material used for manufacturing the duplex stainless steel.

[0031] Microstructural features such as the austenite spacing (the mean distance in the ferrite between the austenite areas) and grain size is influenced by the manufacturing method. The austenite spacing can be reduced by a larger degree of hot working and/or cold working before the solution-annealing heat treatment. A duplex stainless steel with smaller austenite spacing has better HISC-resistance. The austenite spacing of the duplex stainless steel as defined hereinabove or hereinafter in solution-annealed condition is in the range of from 5-35 μm , such as in the range of from 5-20 μm , such as in the range of from 5-15 μm .

[0032] The pitting and crevice corrosion resistance of a stainless steel is primarily determined by the wt% content of Cr, Mo and N. An index used to compare this resistance is the PRE (Pitting Resistance Equivalent), which is described as $\text{Cr}+3.3\text{Mo}+16\text{N}$. For duplex stainless steels, the pitting corrosion resistance is dependent on the PRE value in both the ferrite phase and the austenite phase. This means that the phase with the lowest PRE value will set the limit for localized corrosion resistance of the duplex stainless steel. Thus, the PRE of the duplex stainless steel according to the present invention is at least 31, such as at least 34.

[0033] The proof strength is the load to which a material can be deformed, without changing its dimension. The proof strength ($R_{p0.2}$) of the duplex stainless steel according to the present disclosure in solution annealed condition is in the range of from 450-700 MPa, such as in the range of from 475-650 MPa.

[0034] Higher elongation means higher ductility and this property is considered in forming

[0035] manufacturing processes. Thus, the elongation (A) of the duplex stainless steel according to the present invention in solution annealed condition is in the range of from 15-45%, such as in the range of from 20-45 %, such as in the range of from 25-45 %.

[0036] The duplex stainless steel object may be manufactured according to conventional methods, i.e. casting or forging, followed by hot working and cold working, solution annealing and an optional additional heat treatment. The important step in the manufacturing method is the solution annealing step as this will set the final microstructure

[0037] The object comprised of duplex stainless steel as defined hereinabove or hereinafter is manufactured by a process comprising the following steps:

- a. melting;
- b. casting;
- c. hot working;
- d. cold working;
- e. solution annealing.

[0038] The duplex stainless steel object may be in the form of; a bar, a tube; a seamless or a welded tube, a constructive part, such as for example a flange and a coupling, a plate, a sheet or a strip, or a wire.

[0039] The present invention is further illustrated by the following non-limiting examples.

BRIEF DESCRIPTION OF DRAWINGS

[0040]

Figure 1 discloses HISC-testing at constant load at 4°C in 3 wt% sodium chloride (NaCl) thus simulating the environment which a duplex stainless steel is exposed to in sea water.

EXAMPLES

[0041] Five different heats with different compositions were melted as 270 kg heats in a high frequency induction furnace and cast to ingots using a 9" mould. Table 1 shows the compositions of the duplex stainless steels used. Both inventive and comparative examples are shown below. In Table 1, the points E1 and E2 stand for Example 1 and Example 2 of the present invention, while the points C1-C3 stands for the comparative examples 1-3.

Table 1. Chemical composition of different heats

Heat	C	S	P	Si	Mn	Cr	Ni	Mo	N	Cu	Al	Cr+50N
E1	0.015	0.009	0.005	0.18	0.45	23.79	6.59	2.96	0.14	0.10	>0.003	30.79
E2	0.009	0.005	0.004	0.23	0.42	23.55	6.48	3.96	0.18	0.10	0.007	32.55
C1	0.011	0.005	0.005	0.22	2.13	27.02	7.21	3.97	0.23	0.10	0.014	38.52
C2	0.01	0.005	0.005	0.2	2	23.8	4.73	3.97	0.28	0.10	0.017	37.8
C 3	0.021	0.010	0.005	0.19	0.4	27.3	5.53	2.92	0.33	0.10	>0.003	43.8

[0042] After casting, the mold was removed and the ingot was held at 1050°C for 2 hours and then quenched in water. A sample for chemical analysis was taken from each ingot. The chemical analyses were performed using X-Ray Fluorescence Spectrometry and Spark Atomic Emission Spectrometry and combustion technique.

[0043] The obtained ingots were forged to 130 x 60-70 mm billets in a hammer. Prior to forging, the ingots were heated to 1250-1280°C with a holding time of 2 hours. The forged billets were machined to 120 x 50 mm billets that were hot rolled to 10-12 mm in a Robertson rolling mill. Before hot rolling, the billets were heated to 1150°C-1220°C with a holding time of 1.5-2 hours. After the hot rolling, the billets were held at 1100°C-1120°C for 10 minutes then cooled in air to 900°C-950°C where they were quenched in oil. The duplex stainless steels billets were cold rolled to 7- 8 mm thickness and then heat treated by solution annealing at 1000-1150°C and thereafter cooled in air.

[0044] After the final heat treatment step, HISC-testing was performed at constant load with dead weight testers in a solution of 3 wt% NaCl at 4°C and subject to a cathodic protection at approximately 1050 mV_{SCE}. The testing time was 500 hours or until failure and the load correlated to the proof strength. Prior the experiment, the samples were galvanostatically charged with hydrogen with a current density of 0.02 A/cm².

[0045] When analyzing the results from HISC-testing, it was surprisingly found that the solution annealed duplex stainless steels with a lower Cr and N content had better resistance against HISC. A linear relation between the maximum load without failure in the HISC-testing related to the proof strength ($R_{p0.2}$) at 4 C° and a linear relation to the equation Cr+50N were observed as can be seen from Figure 1. In Figure 1, the points E1 and E2 stand for Example 1 and Example 2 of the present disclosure while the points C1-C3 stands for the comparative examples 1-3. Hence, the objects made of a duplex stainless steel must fulfill the equation that Cr+50xN is less than or equal to 34 to have improved HISC resistance.

[0046] Further, the solution annealed duplex stainless objects was analysed. Tensile testing ($R_{p0.2}$ and R_m) was performed at room temperature in order to determine the yield strength. Elongation (A) was measured according to ISO 6892-1. The ferrite content was measured according to ASTM E562. The austenite spacing was measured according to DNV-RP-F112. These experimental results are shown in Table 2.

Table 2. Experimental results

	$R_{p0.2}$ (MPa)	R_m (MPa)	A(%)	Ferrite (%)	Austenite spacing (μ m)	PRE
E1	500	693	29	51	13.7	35.8
E2	536	769	35	45	10	39.5
C1	618	829	31	56	34	43.8
C2	568	794	34	48	19	41.4
C 3	594	798	32	52	23	41.2

[0047] In Table 2, the points E1 and E2 stand for Example 1 and Example 2 of the present invention, while the points C1-C3 stands for the comparative examples 1-3.

[0048] As can be seen from the results in Table 3, the solution-annealed objects made of duplex stainless steel of the

present invention have an advantageous microstructure with very good mechanical properties as well as corrosion properties. This means that objects made from said duplex stainless steel will withstand the load/stress and hydrogen ingress of hydrogen formed at the steel surface due to the cathodic protection in sea water

applications. Accordingly, the duplex stainless steel objects will have increased life time, since minimization of the risk of equipment damage or any serious accidents by hydrogen induced stress corrosion will be low, if present at all.

Claims

1. Use of a cold worked and solution-annealed object in sea water applications comprising a duplex stainless steel consisting of the composition in weight% (wt %):

C	less than or equal to 0.03;
Si	less than or equal to 0.5;
Mn	less than or equal to 1.0;
Ni	6.0 to 7.0;
Cr	23.0 to 24.0;
Mo	2.5 to 4.5;
N	0.1 to 0.2;
P	less than or equal to 0.03;
S	less than or equal to 0.03;
Cu	less than or equal to 0.3;
Al	less than or equal to 0.10;

Optionally Ti, Ca, Ce and B in an amount of max 0.5 wt% in total;

the balance being Fe and inevitable impurities; wherein the duplex stainless steel fulfills the equation of $Cr+50N \leq 34$;

and wherein the duplex stainless steel has a ferrite phase content in the range of from 40% to 60 % by volume measured according to ASTM E562 and an austenite phase content in the range of 40 to 60 % by volume; in sea water applications;

and wherein the austenite spacing of the duplex stainless steel is in the range of from 5-35 μm measured according to DNV-RP-F112;

and wherein the $PRE = Cr+3.3Mo+16N$ of the duplex stainless steel is at least 31;

and wherein the proof strength ($R_{p0.2}$) of the duplex stainless steel is in the range of from 450-700 MPa;

and wherein the elongation (A) of the duplex stainless steel is in the range of from 15-45%

2. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to claim 1, wherein the content of N is of from 0.12 to 0.20 wt%.
3. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to anyone of proceeding claims, wherein the content of Mo is of from 2.8 to 4.0 wt%.
4. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to anyone of proceeding claims, wherein the content of Cu is less than or equal to 0.2wt%.
5. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to anyone of proceeding claims, wherein the duplex stainless steel fulfills the equation of $Cr+50N \leq 33$.
6. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to anyone of proceeding claims, wherein the object is in the form of; a bar, a tube, a seamless or a welded tube, a constructive part, a plate, a sheet, a strip or a wire.
7. The use of a cold worked and solution-annealed object made of duplex stainless steel according to anyone of proceeding claims, wherein the object is manufactured by the process comprising the following steps:

- a. melting;
- b. casting;
- c. hot working;
- d. cold working;

e. solution annealing and wherein the solution annealing is performed at a temperature above the recrystallisation temperature of said duplex stainless steel.

8. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to claim 7, wherein the solution annealing is performed in a temperature of from in the range of from 1030-1150°C.

9. The use of a cold worked and solution-annealed object comprising of a duplex stainless steel according to anyone of proceeding claims, wherein the use in sea water application is as a cathode.

Patentansprüche

1. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes in Meerwasseranwendungen, der einen Duplexedelstahl umfasst, der aus der folgenden Zusammensetzung in Gewichtsprozent (Gew.-%) besteht:

C	kleiner als oder gleich 0,03,
Si	kleiner als oder gleich 0,5,
Mn	kleiner als oder gleich 1,0,
Ni	6,0 bis 7,0,
Cr	23,0 bis 24,0,
Mo	2,5 bis 4,5,
N	0,1 bis 0,2,
P	kleiner als oder gleich 0,03,
S	kleiner als oder gleich 0,03,
Cu	kleiner als oder gleich 0,3,
Al	kleiner als oder gleich 0,10,

gegebenenfalls Ti, Ca, Ce und B in einer Menge von insgesamt höchstens 0,5 Gew.-%,

wobei der Rest Fe und unvermeidliche Verunreinigungen sind, wobei der Duplexedelstahl die Gleichung $Cr+50N \leq 34$ erfüllt, und wobei der Duplexedelstahl einen Gehalt an Ferritphasen im Bereich von 40 bis 60 Volumen-%, gemessen nach ASTM E562, und einen Gehalt an Austenitphase im Bereich von 40 bis 60 Volumen-% aufweist, und wobei der Austenitabstand des Duplexedelstahls im Bereich von 5-35 μm liegt, gemessen gemäß DNV-RP-F112, und wobei der $PRE = Cr+3,3Mo+16N$ des Duplexedelstahls mindestens 31 beträgt, und wobei die Dehnfestigkeit ($R_{p0,2}$) des Duplexedelstahls im Bereich von 450-700 MPa liegt, und wobei die Dehnung (A) des Duplexedelstahls im Bereich von 15-45% liegt.

2. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus einem Duplexedelstahl nach Anspruch 1 umfasst, wobei der Gehalt an N von 0,12 bis 0,20 Gew.-% beträgt.

3. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus einem Duplexedelstahl nach einem der vorangehenden Ansprüche, wobei der Gehalt an Mo von 2,8 bis 4,0 Gew.-% beträgt.

4. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus einem Duplexedelstahl nach einem der vorangehenden Ansprüche, wobei der Gehalt an Cu weniger als oder gleich 0,2 Gew.-% beträgt.

5. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus einem Duplexedelstahl nach einem der vorangehenden Ansprüche, wobei der Duplexedelstahl die Gleichung von $Cr+50N \leq 33$ erfüllt.

6. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus einem Duplexedelstahl nach einem

der vorangehenden Ansprüche, wobei der Gegenstand in der Form eines Stabes, eines Rohres, eines nahtlosen oder geschweißten Rohres, eines Bauteils, einer Platte, einer Blechs, eines Streifens oder eines Drahtes vorliegt.

7. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes aus Duplexedelstahl nach einem der vorangehenden Ansprüche, wobei der Gegenstand durch das Verfahren hergestellt wird, das die folgenden Schritte umfasst:

- a. Schmelzen,
- b. Gießen,
- c. Warmbearbeitung,
- d. Kaltbearbeitung,
- e. Lösungsglühen, wobei das Lösungsglühen bei einer Temperatur oberhalb der Rekristallisationstemperatur des Duplexedelstahls durchgeführt wird.

8. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes, der einen Duplexedelstahl nach Anspruch 7 umfasst, wobei das Lösungsglühen bei einer Temperatur im Bereich von 1030-1150°C durchgeführt wird.

9. Verwendung eines kaltbearbeiteten und lösungsgeglühten Gegenstandes, der einen Duplexedelstahl nach einem der vorangehenden Ansprüche umfasst, wobei die Verwendung in einer Meerwasseranwendung als Kathode erfolgt.

Revendications

1. Utilisation d'un objet hypere trempé et écroui dans des applications en eau de mer constitué d'un acier inoxydable duplex composé des éléments suivants, la composition étant donnée en % en poids :

C	inférieur ou égal à 0,03 ;
Si	inférieur ou égal à 0,5 ;
Mn	inférieur ou égal à 1,0 ;
Ni	de 6,0 à 7,0 ;
Cr	de 23,0 à 24,0 ;
Mo	de 2,5 à 4,5 ;
N	de 0,1 à 0,2 ;
P	inférieur ou égal à 0,03 ;
S	inférieur ou égal à 0,03 ;
Cu	inférieur ou égal à 0,3 ;
Al	inférieur ou égal à 0,10 ;

Optionnellement Ti, Ca, Ce et B selon une quantité d'au maximum 0,5 % en poids au total ;

le reste étant du Fe et des impuretés inévitables ; où l'acier inoxydable duplex satisfait à l'équation $Cr+50 \leq 34$; et où l'acier inoxydable duplex présente une teneur en phase ferritique dans la plage allant de 40 % à 60 % en volume mesurée conformément à l'ASTM E562 et une teneur en phase austénitique dans la plage allant de 40 à 60 % en volume ;

et où l'espacement austénitique de l'acier inoxydable duplex se situe dans la plage allant de 5 à 35 μm mesuré conformément à DNV-RP-F112 ;

et où le $PRE = Cr+3,3Mo+16N$ de l'acier inoxydable duplex est au moins de 31 ;

et où la limite conventionnelle d'élasticité ($R_{p0,2}$) de l'acier inoxydable duplex se situe dans la plage allant de 450 à 700 MPa ;

et où l'allongement (A) de l'acier inoxydable duplex se situe dans la plage allant de 15 à 45 %.

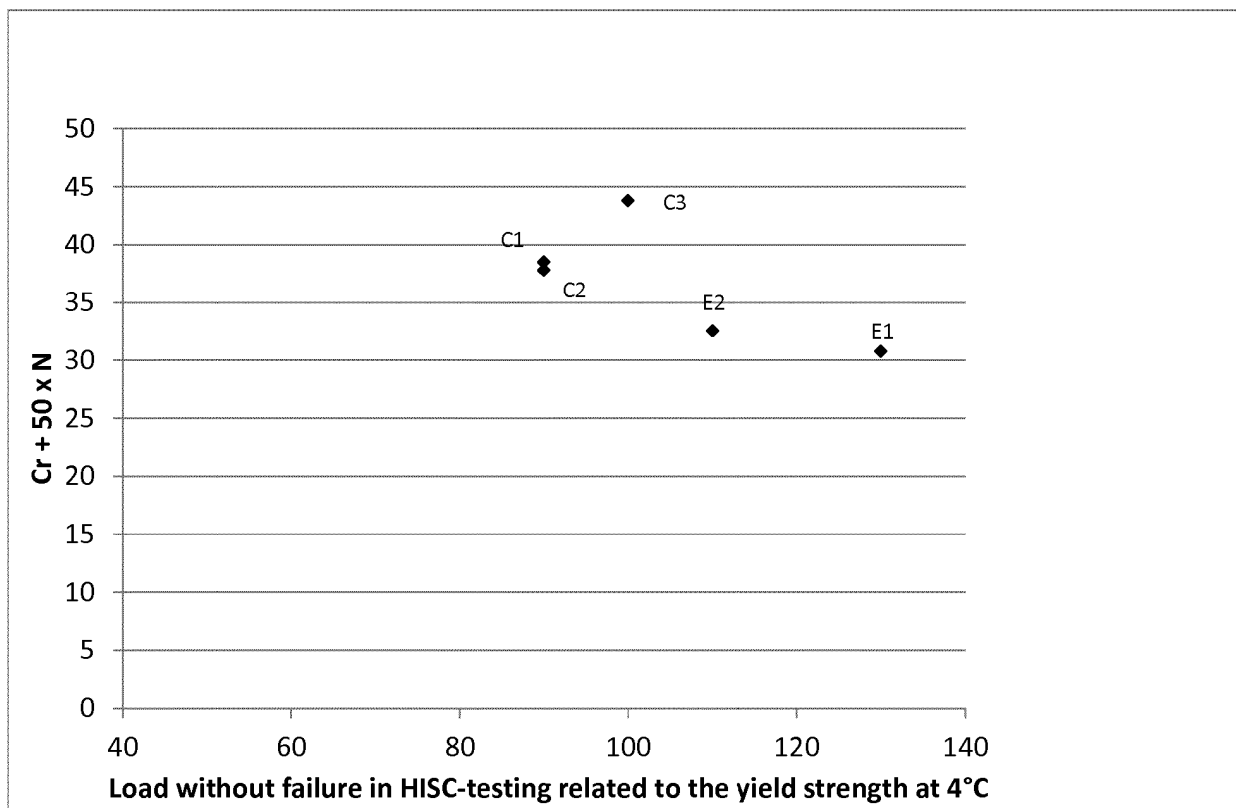
2. Utilisation d'un objet hypere trempé et écroui constitué d'un acier inoxydable duplex selon la revendication 1, où la teneur en N va de 0,12 à 0,20 % en poids.

3. Utilisation d'un objet hypere trempé et écroui constitué d'un acier inoxydable duplex selon l'une quelconque des revendications précédentes, où la teneur en Mo va de 2,8 à 4,0 % en poids.

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4. Utilisation d'un objet hypertrempé et écroui constitué d'un acier inoxydable duplex selon l'une quelconque des revendications précédentes, où la teneur en Cu est inférieure ou égale à 0,2 % en poids.
- 5 5. Utilisation d'un objet hypertrempé et écroui constitué d'un acier inoxydable duplex selon l'une quelconque des revendications précédentes, où l'acier inoxydable duplex satisfait à l'équation $Cr+50N \leq 33$.
- 10 6. Utilisation d'un objet hypertrempé et écroui constitué d'un acier inoxydable duplex selon l'une quelconque des revendications précédentes, où l'objet se présente sous la forme d'une barre, d'un tube, d'un tube sans soudure ou d'un tube soudé, d'une pièce de structure, d'une plaque, d'une tôle, d'une bande ou d'un fil.
- 15 7. Utilisation d'un objet hypertrempé et écroui constitué d'acier inoxydable duplex selon l'une quelconque des revendications précédentes, où l'objet est fabriqué via le procédé comprenant les étapes suivantes :
- a. fusion ;
 - b. coulage ;
 - c. formage à chaud ;
 - d. écrouissage ;
 - e. hypertrempe et où l'hypertrempe est réalisée à une température supérieure à la température de recristallisation dudit acier inoxydable duplex.
- 20 8. Utilisation d'un objet hypertrempé et écroui constitué d'un acier inoxydable duplex selon la revendication 7, où l'hypertrempe est réalisée à une température se situant dans la plage allant de 1030 à 1150 °C.
- 25 9. Utilisation d'un objet hypertrempé et écroui constitué d'un acier inoxydable duplex selon l'une quelconque des revendications précédentes, où l'utilisation dans une application en eau de mer est à titre de cathode.

FIGURE 1



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012140689 A [0004]
- JP 2016053213 A [0004]