

(19)



(11)

**EP 2 093 303 A1**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**26.08.2009 Bulletin 2009/35**

(51) Int Cl.:  
**C22C 38/00 (2006.01) C22C 38/40 (2006.01)**  
**C22C 38/44 (2006.01)**

(21) Application number: **08163637.5**

(22) Date of filing: **04.09.2008**

(84) Designated Contracting States:  
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR**  
Designated Extension States:  
**AL BA MK RS**

(72) Inventors:  
• **Theorin, Jonas**  
**431 66, Mölndal (SE)**  
• **Arne, Gudmundson**  
**433 70, Sävedalen (SE)**

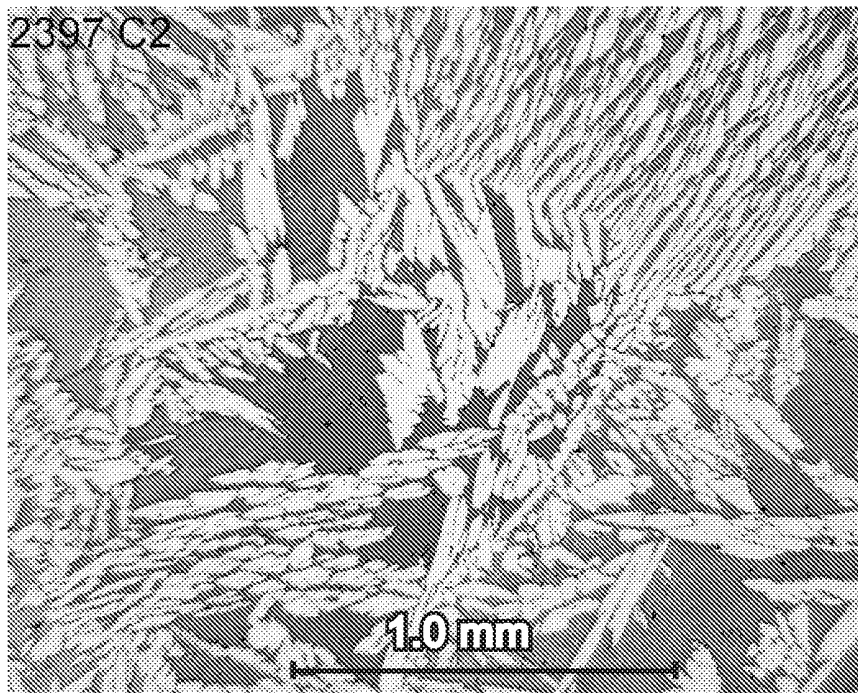
(71) Applicant: **Scanpump AB**  
**431 21 Mölndal (SE)**

(74) Representative: **Andersson, Inga-Lill**  
**Awapatent AB**  
**Box 11394**  
**404 28 Göteborg (SE)**

(54) **Duplex Cast Steel**

(57) The present invention relates to a duplex cast steel having a microstructure comprising 30-50 vol% austenite and 50-70 vol% ferrite, wherein said steel has a composition comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N. By the invention, a duplex steel

which is possible to cast and which has low amount of Nickel compared to currently used standard steels is provided. The inventive steel can be used for chemical process equipment, such as process components in the pulp and paper industry, such as pump and agitator components.



*Amount of ferrite: 57%*

*Magnification: 50X*

*Fig. 1b*

**EP 2 093 303 A1**

**Description**Technical field of the invention

5 **[0001]** The present invention relates to a novel duplex steel which has a low nickel content, and which is suitable for the manufacturing of cast articles. Especially, the novel duplex steel can be used for process components, such as pump and agitator components for use in chemical process industry, for example the pulp and paper industry.

Background of the invention

10 **[0002]** Duplex steels have a microstructure comprising austenite and ferrite. Generally, duplex steels have superior mechanical properties and high corrosion resistance compared to low alloyed ferritic steels. Compared to high-alloyed austenitic steels, duplex steels are less expensive and generally easier to process and also in many applications provide sufficient mechanical properties and corrosion resistance. Therefore, duplex steels can be advantageously used in many applications where otherwise high alloyed stainless steels are needed.

15 **[0003]** Standard duplex steels generally comprise in the range of 4-8 wt% Nickel. There are many existing standard duplex steels commercially available. However, since Nickel is a very expensive metal, steels comprising high amount of Ni are very expensive. Hence, it is desirable to find novel duplex steels with low amount of Nickel, which thus can replace the standard duplex steels.

20 **[0004]** However, such lowering must not be on expense of the reliability of the performance of the steel. The requirements on material properties of such duplex steel include casting aspects, mechanical aspects, and corrosion aspects. The casting properties are very important. Casting properties include for example requirements on microstructure and low porosity of the cast steel. In addition, the formation of undesired inclusions and precipitates must be held at a minimum. The mechanical properties of a material used in chemical process components are important from safety aspects. Requirements on mechanical properties include for example sufficient toughness, strength and hardness. Typically, the material is exposed to high pressures which generally are present or may arise temporary during the service of a chemical process equipment. In addition, the presence of particles in the process flow can contribute to wear, erosion corrosion or the like. At the same time as the material should be hard to withstand wear, it must also exhibit sufficient mechanical processability, since further processing may be desired after the casting step. The requirements on corrosion resistance such as resistance to liquid corrosion and corrosion at elevated temperatures must also be considered. The presence of gaseous, liquid or solid chemicals in the process flow and in the surrounding environment affect the steel in different ways, often results in different types of corrosion. Several degradation mechanisms are often present at the same time in chemical applications, which results in synergetic effects resulting in accelerated degradation.

25 **[0005]** In order to provide reliable and sufficient material properties for a given technical application, a duplex cast steel must fulfil all these requirements including casting aspects, mechanical aspects, and corrosion aspects. In fact, Nickel is an important alloying element which has several important effects on the material properties. Hence, it is a very difficult task to provide such duplex cast steel. The optimal development would be a steel which is less expensive and also provides improved material properties.

30 **[0006]** In recent years, development has resulted in the duplex steel disclosed in WO 02/27056. Due to the low Nickel concentration, this steel can be advantageously used for rolled steel products, relative to standard duplex steels. However, it has been indicated that it can be difficult to obtain cast articles with sufficient casting properties from this steel.

35 **[0007]** Thus, there is a need in the art for finding a novel duplex steel which has a reduced Nickel content compared to standard duplex steels and which provides sufficient casting properties, as well as sufficient or improved material properties and a reliable lifetime for use in chemical process equipment.

45

Summary of the invention

**[0008]** It is an object of the present invention to at least partly overcome the above-mentioned problems of the prior art and to at least partly meet the needs in the art, and thus to provide a novel duplex cast steel comprising a lower amount of Nickel than currently used standard duplex steels suitable for casting.

50 **[0009]** A general object is to provide a duplex cast steel, which has a high performance, that is, fulfils requirements on casting and have sufficient or improved material properties, including mechanical aspects and corrosion aspects. The material properties of duplex cast steel process components are of critical importance in the chemical process industry, since a sudden failure of the material can cause instant danger, very costly emergency stops and high renovation costs.

55 **[0010]** Accordingly, a further general object of the present invention is to provide a duplex cast steel with high performance, which is suitable for use in cast articles for components for use in the chemical process industry, such as in the pulp and paper, oil, chemical, organic, food, sugar, mining or bio fuel industry or for district heating. As used herein,

the term "process component" refers to any cast article which comprises the present steel composition. For example, one object is to provide a duplex cast steel, which is suitable for the manufacturing of articles such as machine parts, or components for pumps and agitators. Pump components include pump casings, impellers, wear discs, casing covers, seal housings, shaft couplings and propeller hubs.

5 [0011] These and other objects are achieved by materials and products of the present invention.

[0012] In a first aspect, the present invention provides a duplex cast steel having a microstructure comprising 30-50 vol% austenite and 50-70 vol% ferrite, wherein said steel has a composition comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N. The obtained duplex structure and the chemical composition provide a novel and inventive duplex steel which compared to currently used standard steels comprises a low amount of Nickel and is suitable for casting articles. It was found that the obtained cast steel has both good casting properties and good material properties, sufficient for many different technical applications, where high material performance is needed, such as in the pulp and paper, oil, chemical, organic, food, sugar, mining or bio fuel industry or for district heating and other chemical process industries.

10 [0013] A second aspect of the invention, relates to the use of the duplex cast steel of the invention in cast articles. It was found that the inventive steel is useful for process components for instance in the pulp and paper industry, oil industry or organic industry, since the present composition of steel is both possible to cast and also meet the criteria on material reliability both in terms of mechanical aspects and corrosion aspects.

[0014] A third aspect of the invention relates to a cast article made from the duplex cast steel of the present invention. The cast article is typically a machine part such as a pump or agitator component.

20 [0015] A fourth aspect of the invention relates to a method for providing a cast article comprising providing a melt comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N in a mould; and allowing the melt to solidify into a cast steel article comprising 30-50 vol% austenite and 50-70 vol% ferrite.

[0016] Embodiments of the invention will now be described in more detail with reference to the accompanying schematic drawings, which by way of examples illustrate currently preferred embodiments of the invention.

25 Brief Description of the drawings

[0017]

30 Fig. 1a shows an image of the microstructure of a part of the surface of a cast article of the steel according to the invention.

Fig. 1b shows a cross-sectional image of the microstructure close to the inner core of a cast article of the steel according to the invention.

35 Fig. 2a shows an image of the microstructure of a part of the surface of a cast article of the steel according to the invention, which has been annealed.

Fig. 2b shows a cross-sectional image of the microstructure close to the inner core of a cast article of the steel according to the invention, which has been annealed.

Fig. 3 shows results from a abrasion and corrosion test in water (at pH 7) with the novel duplex cast steel compared to a standard duplex steel and an austenitic steel.

40 Fig. 4 shows results from a abrasion and corrosion test in white liquor (at pH 13) with the novel cast steel compared to a standard duplex material and an austenitic steel.

Fig. 5 shows results from a abrasion and corrosion test in sulphuric acid (at pH 2) with the novel casting material compared to a standard duplex steel and an austenitic steel.

45 Detailed description of the invention

[0018] According to the first aspect, the present invention relates to a duplex cast steel having a microstructure comprising 30-50 vol% austenite and 50-70 vol% ferrite, wherein said steel has a composition comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N. The obtained duplex structure and the chemical composition provide a novel duplex steel which compared to currently used standard steels comprise a low amount of Nickel and is suitable for casting articles. Since the amount of Nickel is lowered, the steel is less expensive than standard duplex steels. By using a Nickel concentration of at most 3.40 wt% combined with a moderate nitrogen concentration, it was found that the obtained cast steel had both good casting properties and unexpected good material properties, sufficient for many different technical applications, where high material performance is needed, for example in the pulp and paper industry, oil industry and organic industry.

55 [0019] The steel will be particularly useful for cast process articles, such as components for pumps and agitators.

[0020] Nickel is a very important alloying element since it strongly contributes to the austenite formation. Nickel also contributes importantly in many other different ways, for example to the corrosion resistance and to the mechanical

properties of the material. Typically, the duplex cast steel according to the present invention comprises 0.50-3.40 wt% Ni, such as at least 1.80-3.35 wt% Ni or in the range of 2.50-3.35 wt% Ni.

5 [0021] Nitrogen is commonly known as being a dominating austenite former and as contributing to the strength and corrosion resistance of the steels. By lowering the amount of nitrogen to 0.14 wt% or below, it was found that the casting properties were significantly improved, but essentially without negative impact on the material properties of the cast steel. Typically, the duplex cast steel according to embodiments of the present invention may comprise 0.12 wt% N or less, such as in the range of 0.08-0.12. It was found that by this moderate amount of nitrogen, pore formation and undesired precipitates can be avoided.

10 [0022] Chromium is especially important for the corrosion resistance, it is also an important ferrite former and contributes by improving the mechanical properties. Therefore, an amount of chromium of 18-27 wt% is used in the steel composition. In embodiments of the present invention, the duplex cast steel may be specified to in the range of 18-25 wt% of Cr, such as in the range of 20-23 wt% Cr or 21-23 wt% Cr in order to obtain a balanced content of ferrite and austenite and to provide a sufficient corrosion resistance. If the chromium level is lower than specified above, there is a risk for the formation of martensite in the material. A higher amount of chromium than specified above may result in precipitation of intermetallic phases.

15 [0023] According to the invention, iron is used as balance in the steel composition, meaning that iron is present in the steel in a concentration which results in that the sum of the concentrations of the present elements is 100 %.

20 [0024] The microstructure of the duplex cast steel according to the present invention comprises 30-50 vol% austenite and 50-70 vol% ferrite. In embodiments of the present invention, the steel comprises 35-45 vol% austenite and 55-65 vol% ferrite, such as 40-45 vol% austenite and 55-60 vol% ferrite. By a proper balance between austenite and ferrite in duplex steels, the mechanical and corrosion resistance properties are optimized.

25 [0025] In embodiments of the invention, the duplex cast steel may comprise 3-8 wt% Mn, such as 3-5 wt% Mn. Manganese is known as an austenite former, and increases the solubility of nitrogen. However, if too much nitrogen is dissolved into the steel, it may result in reduced casting properties. Therefore the amount of Manganese preferably is within the specified range.

30 [0026] In embodiments of the invention, the duplex cast steel may comprise up to 1 wt% Mo, such as in the range of 0.3-0.6 wt% Mo. Molybdenum is optionally added to the steel composition due to its strong contribution to ferrite formation and since it can enhance the corrosion resistance. However, Molybdenum is a very expensive metal and is therefore only added in small amounts if required. Further, the silicon content in embodiments of the inventive steel may be up to 2 wt%, such as 1-2 wt% Si. Silicon stabilizes the high temperature strength of the ferrite at elevated temperatures and is hence very important during the casting process. Moreover, it reduces the solubility of nitrogen.

35 [0027] In embodiments of the inventive steel, the carbon content may be up to 0.05 wt%. Carbon is an austenite former and contributes to the strength of the steel. A high amount of carbon generally results in the formation of intermetallic carbides. Such carbides can negatively affect the corrosion resistance and result in reduced toughness characteristics. Hence, the a low carbon concentration in the steel according to the invention is used.

40 [0028] According to the second aspect, the invention relates to the use of the inventive duplex cast steel in cast articles, for example in process components in chemical process equipment. It was found that a cast article according to the invention can be used for process components or machine parts in a chemical process, such as for example in pulp and paper processing and for instance in the oil industry or organic industry, since the steel according to the invention is both possible to cast and also meet the criteria on material reliability both in terms of mechanical aspects and corrosion aspects. The inventive steel can for example be used in a machine parts, pump components and agitator components.

45 [0029] According to the third aspect, the invention relates to a cast article made from the duplex cast steel of the invention. By using a steel according to the present invention, articles which are less expensive but provide the same or sufficient properties than existing articles are possible to obtain.

50 [0030] The cast article is typically a process component or a machine part for use in a chemical process, such as for pulp and paper processing, or a pump or agitator component. These kinds of articles are generally exposed to very complex environments where high performance and reliable lifetime are of critical importance from safety aspects and economical aspects. For example, pump and agitator components are frequently exposed to high pressures and/or elevated temperatures. In addition, they are often exposed to acidic or alkaline fluids such as liquids, emulsions or dispersions containing solid particles. A material with high performance is needed in order to ensure a reliable lifetime. Currently used pump components are expensive, since they are made of standard duplex steel or austenitic steels. Hence, it is desirable to switch to a less expensive material with high performance. Therefore, a novel duplex steel which is less expensive and which provides sufficient or optimally improved material properties is desired. The term "article" used herein, refers to any product or component comprising the duplex cast steel according to the invention.

55 [0031] According to the fourth aspect, the invention relates to a method for providing a cast article comprising providing a melt comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N in a mould; and allowing the melt to solidify into a cast steel article comprising 30-50 vol% austenite and 50-70 vol% ferrite. The analysis results (see examples 1-3) from cast articles manufactured according to the method, show that the articles exhibit sufficient material performance

for use in industrial applications such as process components for use in in chemical process industry.

**[0032]** Although the present invention has been described in connection with particular embodiments thereof, it is to be understood that various modifications, alterations and adaptations may be made by those skilled in the art without departing from the claimed scope.

**[0033]** For example, the present steel may, in addition to the austenite structure and ferrite structure, have an intentional or unintentional minor content of other structural phases. For example a low amount of precipitates like carbides and intermetallic compounds may be present in the steel.

**[0034]** The steel may also comprise other elements in order to further provide desired properties of steel. The elements may be present intentionally or unintentionally. Intended elements may include for example Tungsten, Boron, Niobium and Copper or any other elements that are added in order to provide beneficial effects. Unintended elements may include trace elements, which are present in the raw steel material or in the surrounding environment to which the steel is exposed during manufacturing.

**[0035]** It should also be understood that any kind of casting technique which results in a microstructure and composition according to the invention can be used for obtaining a cast article according to the present invention. This includes for example casting techniques currently used for standard duplex steels.

**[0036]** As long as the requirements of the material is obtained, any method can be used where liquid material is poured into a mould of a desired shape, and then allowed to solidify. The mould is generally cooled in air, however the cooling rate can optionally be controlled. In addition, the shaped cast article may be further heat treated, annealed or processed such as mechanically processed to obtain fine shapes or surface texture. Especially, the steel can be heat treated in order to control the microstructure of the steel.

**[0037]** Below, an example of the duplex cast steel of the present invention is presented. The examples are provided in order to illustrate the invention and should not be regarded as limiting the scope of the invention.

#### Example 1

**[0038]** In this example test rods were moulded by conventional sand casting. The test rods were allowed to cool in air. The microstructure of the obtained rods was analysed using a microscope. The obtained steel composition is shown in Tab. 1.

*Table 1.*

	<b>Cr</b>	<b>Ni</b>	<b>Mo</b>	<b>N</b>	<b>Mn</b>	<b>Si</b>	<b>C</b>	<b>P</b>	<b>S</b>	<b>Fe</b>
<b>Wt%</b>	20,99	3.32	0.44	0.119	4.16	1.58	0.03	0.021	0,003	balance

**[0039]** Referring now to Fig.1a and b, showing two examples of micrographs of the microstructure of the cast steel, Fig. 1a shows the surface of the obtained steel while Fig. 1b shows a cross-section view of the inner close to the centre of a rod. The amount of ferrite and austenite was then calculated from the images. The amount of ferrite in Fig. 1a was calculated to about 58%, and in Fig. 1b to about 57% ferrite.

**[0040]** Referring now to Fig. 2a and b, showing two examples of micrographs of the microstructure of the cast steel after annealing at 1050 °C, Fig. 2a shows the surface of the obtained steel, while Fig. 2b shows a cross-section view of an inner part close to the centre of a rod. The amount of ferrite in Fig. 2a was calculated to about 55%, and in Fig. 2b to about 57% ferrite.

**[0041]** During the investigation of the steel microstructure, austenite and ferrite were found, and no other steel phases.

**[0042]** The Fig. 1 and Fig. 2 clearly show that a dense steel is formed and that undesired inclusions and pores are essentially absent in the material. From these results, it is demonstrated that the novel duplex cast steel, comprising a lower amount of Nickel than currently used standard steels used for casting, fulfils the requirements on casting.

#### Example 2

**[0043]** In this example the mechanical properties of the test rods from example 1 were investigated. Test rods having a diameter of 10 mm were used in the tests. The results are presented in Tab. 2, showing the yield strength at 0.2% permanent elongation ( $R_{p0.2}$ ), the ultimate tensile strength ( $R_m$ ), % elongation at fracture and % reduction of area at fracture. The testing was performed in room temperature and at 150°C. In addition, the hardness of the test rods was measured to 220-225 HV.

EP 2 093 303 A1

Table 2.

Test rod nr	Rp0,2 (N/mm <sup>2</sup> )	Rm (N/mm <sup>2</sup> )	% elongation at fracture	% reduction of area at fracture
<b>At room temperature:</b>				
1 (cast)	435	628	22	18
2 (cast)	450	638	27	19
3 (cast and annealed)	449	648	26	32
<b>At 150°C:</b>				
1 (cast)	357	557	37	61
2 (cast)	342	568	36	63
3 (cast and annealed)	357	554	36	61

[0044] From the test results in Tab. 2, it is concluded that the obtained cast steel has mechanical properties which fulfils requirements that in many cases are specified for high performance applications in chemical process equipment, such as process components in the pulp and paper industry.

[0045] Annealing was carried out at 1050°C in order to further improve the mechanical characteristics. By annealing, the microstructure of the cast material is altered to improve mechanical properties such as strength, toughness and hardness.

[0046] The results in Tab. 2 showing the analysis of the annealed material, demonstrates that that the annealed cast steel provides mechanical properties which are further improved. However, for certain applications annealing may not be necessary to provide sufficient mechanical properties.

Example 3

[0047] In this example, the corrosion resistance was investigated theoretically and experimentally. In addition, the combined effect of abrasion and corrosion of a steel according to the invention was investigated.

[0048] The pitting resistance equivalent, PRE value, can be calculated from the formula:

$$PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N.$$

[0049] The PRE value of the novel duplex cast steel composition was calculated to be 24 for the cast steel according to the composition in Example 1. Hence, the novel duplex cast steel provides theoretically a corrosion resistance which is sufficient for use in chemical process equipment. It may be noted that it is very difficult to evaluate the performance of a material by this simple calculation, since the material in use generally is exposed to complex environments.

[0050] Experiments were carried out in order to evaluate the combined effect of abrasion and corrosion of the steel of the present invention. It should be noted that this experiment do not mimic the conditions in a real application where the steel is used, but is rather a testing method using accelerated conditions. The results from these tests are hence not indicative values of the wear in a real environment. However, the results can be used in order to compare the combined abrasion and corrosion properties of different materials.

[0051] In the tests an annealed steel according to the present invention, denoted as 2397N in Fig. 3-5 was compared with two different reference steels which are currently used, for example in pump parts. The annealing of 2397N was performed at 1050°C. As reference steels, a standard duplex steel, SS 2324, and a standard austenitic steel, SS 2343 were used.

[0052] Two steel specimens of each alloy were mounted onto a rotor which was placed on top of a reaction container. The samples were then exposed to water, white liquor or sulphuric acid, combined with 10% glass solids at 50 °C. The samples were weighed before and after exposure, and the mass change was calculated as gram/year. The experiment was carried out first in a low corrosive environment, water, thereafter, the experiment was repeated in an acidic and an alkaline environment.

[0053] Referring now to Fig. 3, showing the results from the abrasion/corrosion test in water (pH7). It was shown that the tested steels provide comparable abrasion and corrosion behaviour in this environment.

[0054] Referring now to Fig. 4, showing the results from the abrasion/corrosion test in white liquor (pH 13). It was

clearly shown that the exposed novel steel in this environment provides improved corrosion and abrasion resistance both compared to the standard duplex steel and to the austenitic steel.

[0055] Referring now to Fig. 5, showing the results from the abrasion/corrosion test in sulphuric acid (pH 2). As can be concluded from the results, the novel steel has comparable corrosion and abrasion resistance compared to the standard duplex steel and improved performance compared to the austenitic steel in this environment.

[0056] These test results show that the inventive steel fulfils the requirements on corrosion and abrasion resistance, since the test results were comparable with currently used steels. Actually, it was found that the steel according to the invention has improved corrosion and abrasion resistance compared to the reference steels in the alkaline test environment.

[0057] To summarize, the present invention relates to a duplex cast steel having a microstructure comprising 30-50 vol% austenite and 50-70 vol% ferrite, wherein the steel has a composition comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N. By the invention, a duplex steel which is possible to cast and which has low amount of Nickel compared to currently used standard steels is provided. The inventive steel can be used for chemical process equipment, such as process components in the pulp and paper industry, such as pump and agitator components.

### Claims

1. A duplex cast steel having a microstructure comprising 30-50 vol% austenite and 50-70 vol% ferrite, wherein said steel has a composition comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up to 0.14 wt% N.
2. A duplex cast steel according to claim 1, wherein said cast steel comprises 35-45 vol% austenite and 55-65 vol% ferrite.
3. A duplex cast steel according to any of the preceding claims, wherein said composition comprises 1.80-3.35 wt% Ni, such as in the range of 2.50-3.35 wt% Ni.
4. A duplex cast steel according to any of the preceding claims, wherein said composition comprises in the range of 18-25 wt% Cr, such as in the range of 20-23 wt% Cr.
5. A duplex cast steel according to any of the preceding claims, wherein said composition comprises up to 0.12 wt% N, such as in the range of 0.08-0.12.
6. A duplex cast steel according to any of the preceding claims, wherein said composition further comprises 3-8 wt% Mn, such as 3-5 wt% Mn.
7. A duplex cast steel according to any of the preceding claims, wherein said composition further comprises up to 1 wt% Mo, such as in the range of 0.3-0.6 wt% Mo.
8. A duplex cast steel according to any of the preceding claims, wherein said composition further comprises up to 2 wt% Si, such as 1-2 wt% Si.
9. A duplex cast steel according to any of the preceding claims, wherein said composition further comprises up to 0.05 wt% C.
10. Use of a duplex cast steel composition according to any of the preceding claims in a cast article.
11. Use of a duplex cast steel composition according to claim 10, wherein said cast article is a process component or a machine part for use in a chemical process, such as for pulp and paper processing.
12. A cast article comprising a steel composition according to any of the claims 1 to 9.
13. A cast article according to claim 12, wherein said article is a process component or a machine part for use in a chemical process, such as for pulp and paper processing.
14. A cast article according to claim 12 or 13, wherein said article is a pump or agitator component.
15. Method for providing a cast article comprising providing a melt comprising 0.50-3.40 wt% Ni, 18-27 wt% Cr and up

## EP 2 093 303 A1

to 0.14 wt% N in a mould;  
and allowing said melt to solidify into a cast steel article comprising 30-50 vol% austenite and 50-70 vol% ferrite.

5

10

15

20

25

30

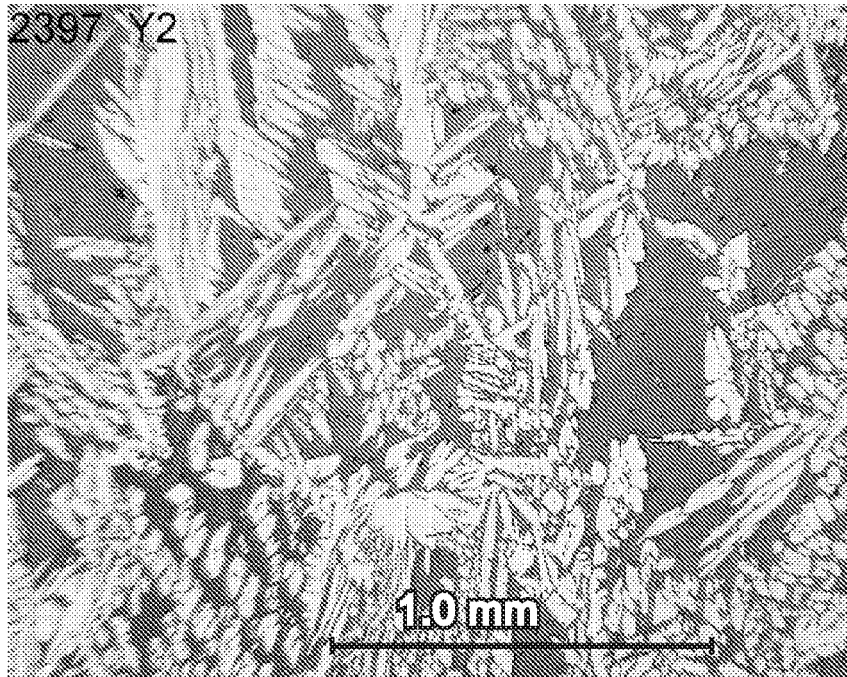
35

40

45

50

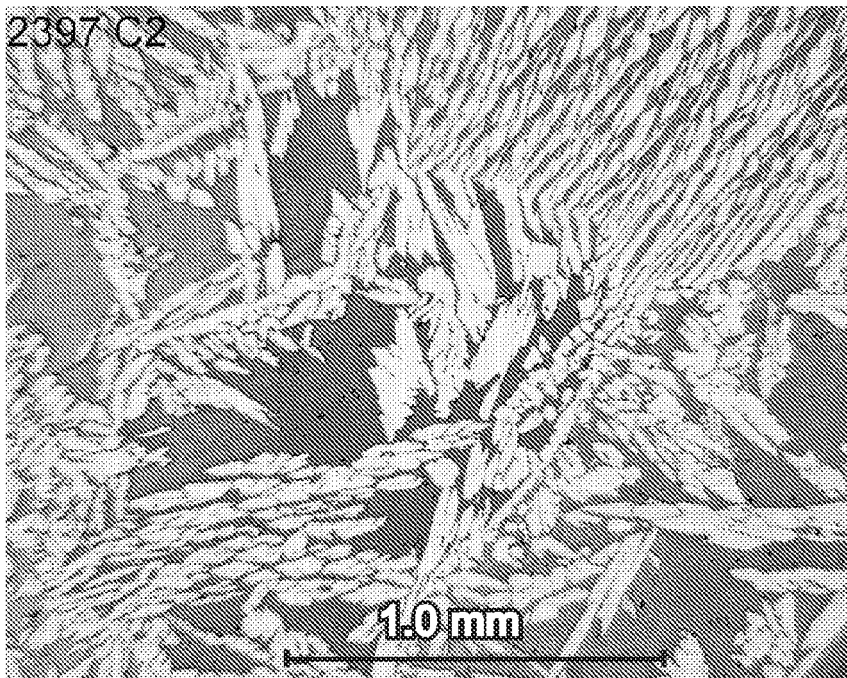
55



Amount of ferrite: 58%

Magnification: 50X

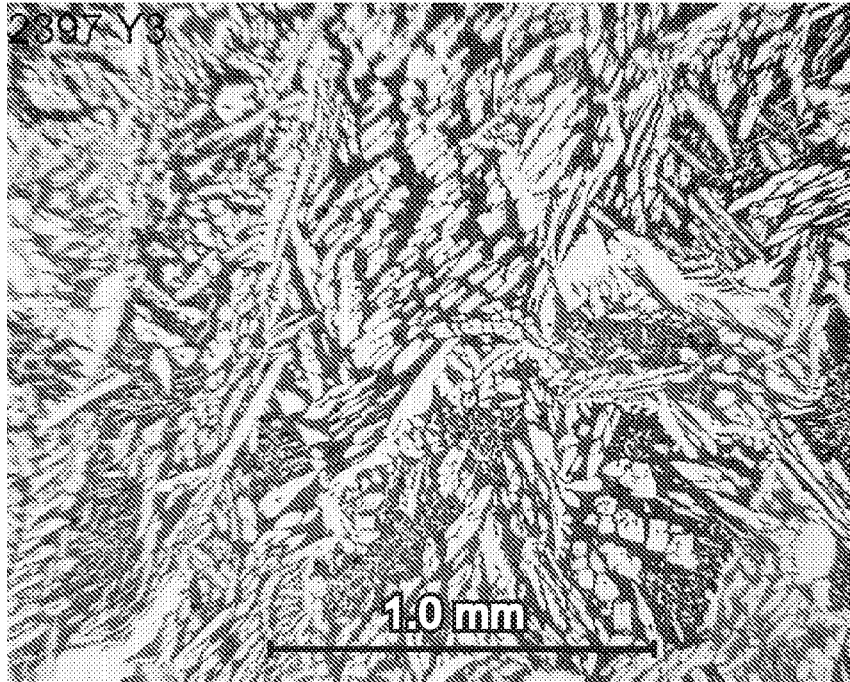
*Fig. 1a*



Amount of ferrite: 57%

Magnification: 50X

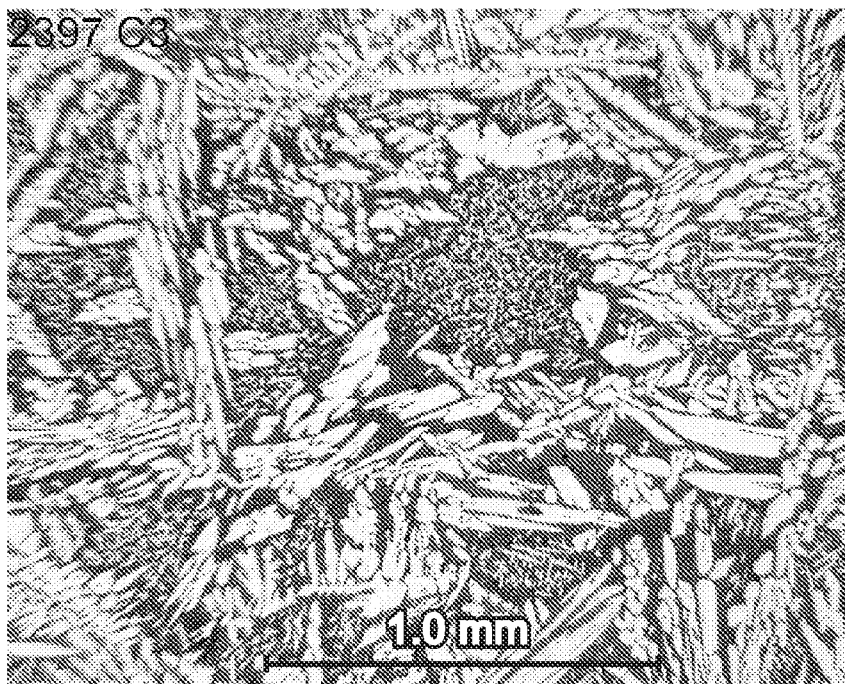
*Fig. 1b*



Amount of ferrite: 55%

Magnification: 50X

*Fig. 2a*



Amount of ferrite: 57%

Magnification: 50X

*Fig. 2b*

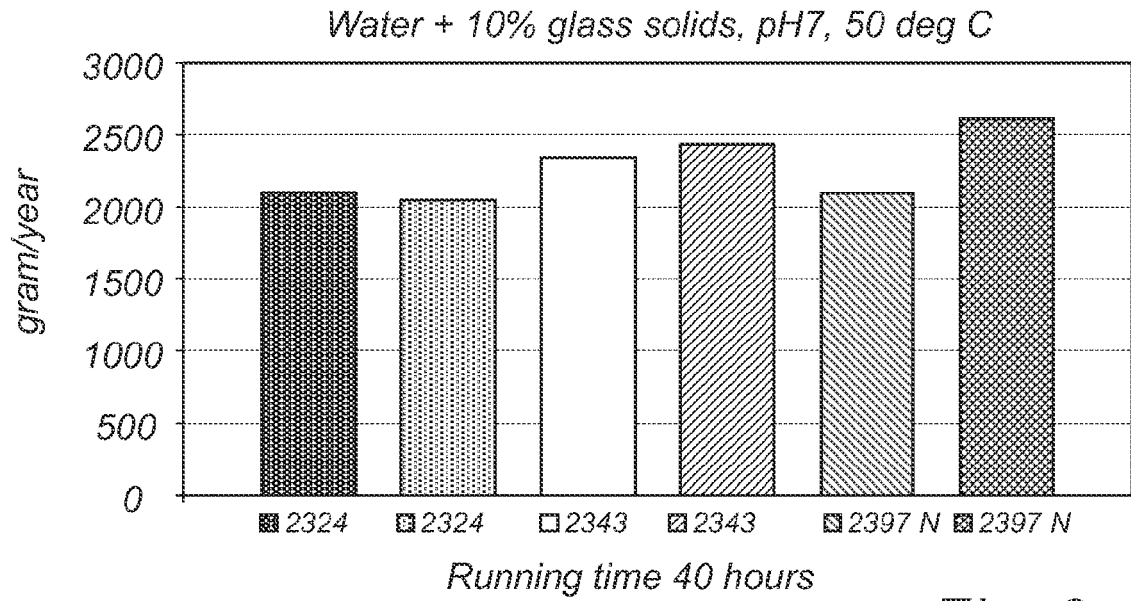


Fig. 3

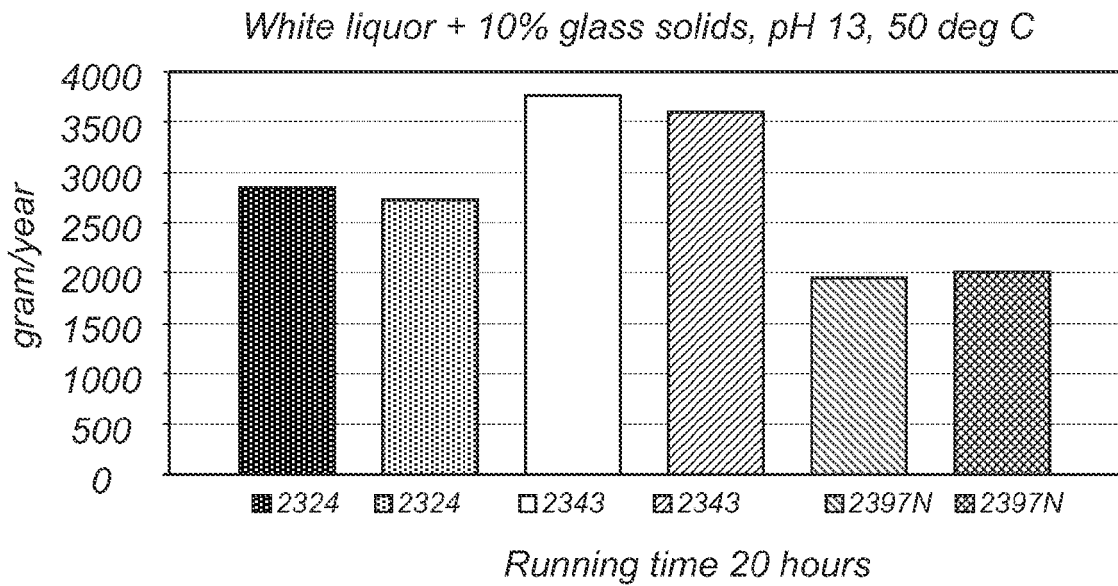
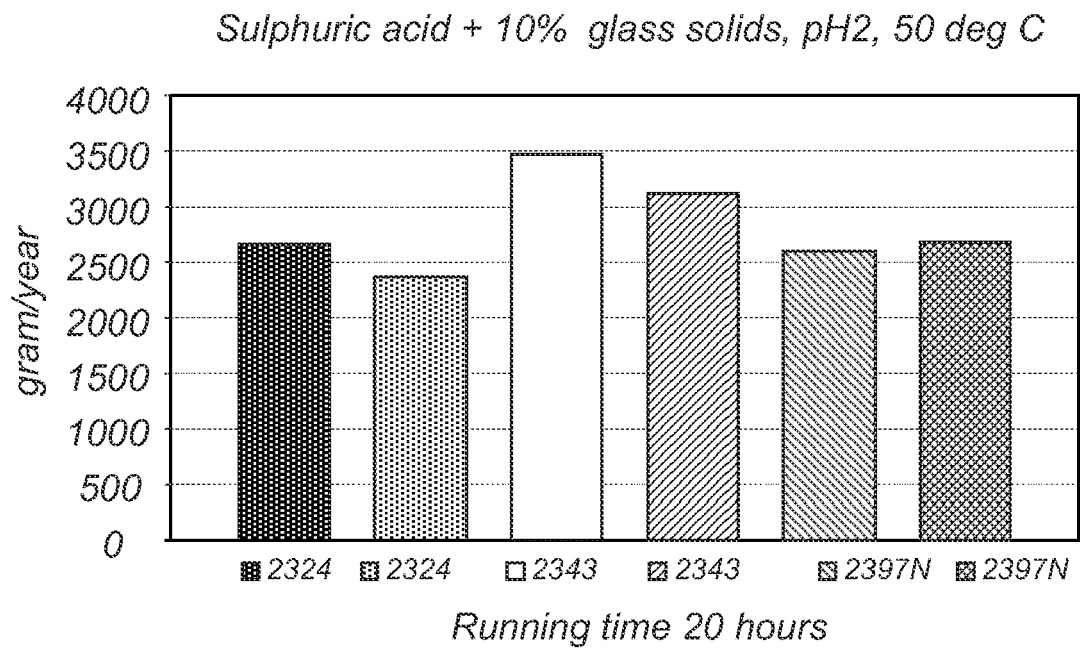


Fig. 4



*Fig. 5*



## EUROPEAN SEARCH REPORT

 Application Number  
 EP 08 16 3637

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 061 151 A (KUBOTA KK [JP]) 20 December 2000 (2000-12-20) * paragraphs [0013] - [0025]; claims 1,5; table 1 *	1-5, 7-13,15	INV. C22C38/00 C22C38/40 C22C38/44
X	EP 0 327 053 A (ARMCO ADVANCED MATERIALS [US]) 9 August 1989 (1989-08-09) * page 3, line 50 - line 58; claim 1; table 1 *	1-10,12, 15	
A	* page 4, line 15 - line 20 *	11,12,14	
X	EP 0 156 778 A (SANTRADE LTD [CH]) 2 October 1985 (1985-10-02)	1-13,15	
A	* claims 1,3-15; tables 1-3 *	14	
X	JP 02 305940 A (NIPPON STEEL CORP) 19 December 1990 (1990-12-19) * examples 1-10 *	1-9	
A	EP 0 314 649 A (SANDVIK AB [SE]) 3 May 1989 (1989-05-03) * page 3, line 25 - line 65; examples 332,451; tables 1,2 *	1-9	TECHNICAL FIELDS SEARCHED (IPC) C22C
A	WO 2006/071027 A (POSCO [KR]; KIM KWANG TAE [KR]; LEE YONG HEON [KR]; SON WON QEUN [KR]) 6 July 2006 (2006-07-06) * figures 1-5 *	1-9	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 February 2009	Examiner Lilimpakis, Emmanuel
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	

1

EPO FORM 1503 03 82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.

EP 08 16 3637

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-02-2009

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1061151	A	20-12-2000	AT 239104 T	15-05-2003
			DE 60002392 D1	05-06-2003
			DE 60002392 T2	25-03-2004
			JP 3508095 B2	22-03-2004
			JP 2000355738 A	26-12-2000
			US 6344094 B1	05-02-2002
-----				
EP 0327053	A	09-08-1989	AR 247249 A1	30-11-1994
			AT 76445 T	15-06-1992
			BR 8900374 A	26-09-1989
			CA 1324729 C	30-11-1993
			DE 68901538 D1	25-06-1992
			ES 2032224 T3	16-01-1993
			IN 171008 A1	27-06-1992
			JP 1225754 A	08-09-1989
			JP 2701913 B2	21-01-1998
			US 4828630 A	09-05-1989
			ZA 8900088 A	28-03-1990
-----				
EP 0156778	A	02-10-1985	AU 566982 B2	05-11-1987
			AU 3981285 A	03-10-1985
			BR 8501432 A	26-11-1985
			CA 1243862 A1	01-11-1988
			DE 3567228 D1	09-02-1989
			DK 142585 A	01-10-1985
			JP 1941545 C	23-06-1995
			JP 4042464 B	13-07-1992
			JP 61056267 A	20-03-1986
			NO 851279 A	01-10-1985
			SE 451465 B	12-10-1987
			SE 8401768 A	10-11-1985
			US 4798635 A	17-01-1989
			ZA 8502013 A	27-11-1985
-----				
JP 2305940	A	19-12-1990	JP 2043102 C	09-04-1996
			JP 7068603 B	26-07-1995
-----				
EP 0314649	A	03-05-1989	DE 3884339 D1	28-10-1993
			DE 3884339 T2	20-01-1994
			JP 1208436 A	22-08-1989
			JP 2801222 B2	21-09-1998
			SE 459185 B	12-06-1989
			SE 8704155 A	27-04-1989
US 5047096 A	10-09-1991			
-----				
WO 2006071027	A	06-07-2006	CN 101090988 A	19-12-2007

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 16 3637

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-02-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006071027 A		EP 1838890 A1	03-10-2007
		JP 2008525636 T	17-07-2008
		KR 20060074400 A	03-07-2006
		US 2008112840 A1	15-05-2008
-----			

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- WO 0227056 A [0006]