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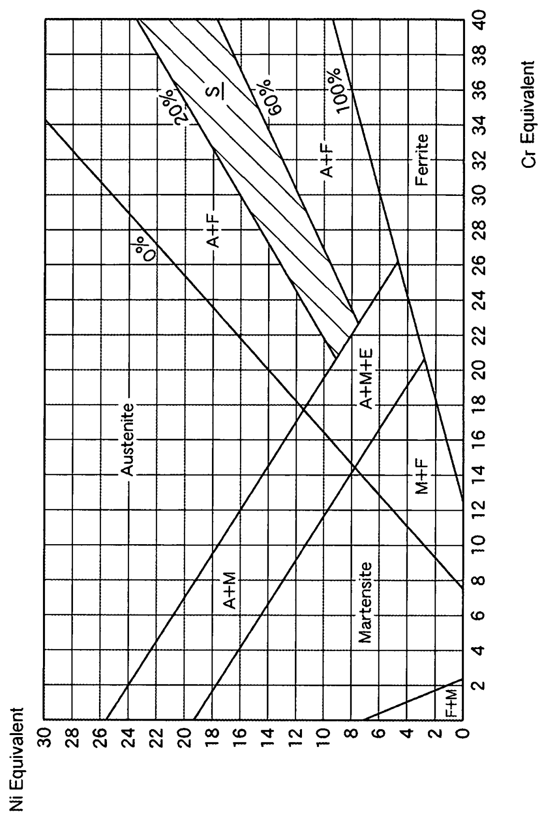
(54) **Two-phase stainless steel**

(57) The present invention relates to a two-phase stainless steel having a ferrite phase and an austenite phase, containing specific contents of C, Si, Mn, Ni, Cr, Cu, N and Fe, and unavoidable impurities, and having an area ratio of the ferrite phase in a range between 20% and 60%.

[FIG. 2]



EP 1 956 109 A1

Description

[0001] The present invention relates to a two-phase stainless steel having a ferrite phase and an austenite phase and also relates to a cast article of the two-phase stainless steel.

[0002] A two-phase stainless steel having a ferrite phase and an austenite phase is now used as a raw material of various members because of its excellent corrosion resistance.

[0003] Patent Document 1 as specified later proposes a two-phase stainless steel for a large-sized article. The proposed stainless steel is composed of up to 0.02 mass % of C, up to 2.0 mass % of Si, up to 2.0 mass % of Mn, up to 0.04 mass % of P, up to 0.04 mass % of S, 3 to 7 mass % of Ni, 17 to 27 mass % of Cr, 0.5 to 6.0 mass % of Mo, 1 to 5 mass % of Cu, up to 3 mass % of W, 0.05 to 0.3 mass % of N, 0.0005 to 0.0015 mass % of B and the balance being Fe.

[0004] The contents of individual elements of the proposed stainless steel are optimized to prevent a σ phase, carbides and nitrides from being formed during the fabrication of a thick cast product such as a propeller blade for a large marine vessel because of slow cooling rate, to adversely affect both corrosion resistance and toughness of the product.

[0005] Patent Document 2, as specified later, proposes a two-phase stainless steel having high mechanical strength and corrosion resistance against seawater. The disclosed stainless steel is composed of up to 0.06 mass % of C, 1.5 to 3.5 mass % of Si, 0.1 to 3.0 mass % of Mn, 2 to 8 mass % of Ni, 18 to 28 mass % of Cr, 0.1 to 0.9 mass % of Mo, 0.03 to 0.2 mass % of N, and the balance being Fe.

Patent Document 1: JP-B-3270498

Patent Document 2: JP-A-H09-302446

[0006] In the known two-phase stainless steel, the austenite and ferrite phases are formed by using Cr and various other elements. Namely, the inclusion of various elements within respective ranges required is essential in order to form the austenite and ferrite phases within a desired ratio thereof.

[0007] Of such elements, similar to Cr, Mo is also an essential element to improve corrosion resistance, especially corrosion against a reducing environment, of the two-phase stainless steel. However, Mo is not only expensive but also tends to adversely affect the mechanical property such as toughness of the stainless steel as the content thereof increases. Although an attempt has been made to reduce the Mo content in the aforementioned JP-A-H09-302446, Mo must be inevitably used in order to obtain the desired corrosion resistance.

[0008] A stainless steel has been hitherto used for a cast article having a thinner portion thereof, such as a propeller blade of a propulsion unit for small watercrafts. In producing such a cast article having a thinner portion, a melt poured into a mold is liable to be cooled at the thinner potion forming section of the mold and its fluidity is therefore apt to be reduced there. When the difference between the pouring temperature and the melting point of the stainless steel is small, therefore, the melt cannot flow sufficiently into the thinner portion forming section. This is likely to cause defects, such as incomplete filling, in the cast product.

[0009] If the pouring temperature is increased to ensure a sufficient difference from the melting point for prevention of occurrence of the incomplete filling, then the temperature of the melt introduced into the mold will be also increased correspondingly, resulting in application of a great thermal load to the mold and generation of a gas during casting operation. The use of such a high temperature melt is therefore disadvantageous.

[0010] It is therefore an object of the present invention to provide a two-phase stainless steel which is substantially free of Mo, which uses a reduced number of kinds of elements, and which shows satisfactory mechanical strength and corrosion resistance and a method for manufacturing such a two-phase stainless steel.

[0011] For the apparatus aspect, this objective is solved by a two-phase stainless steel having a ferrite phase and an austenite phase containing specific contents of C, Si, Mn, Ni, Cr, Cu, N and Fe, and unavoidable impurities, and having an area ratio of the ferrite phase in a range between 20% and 60%.

[0012] With the present teaching, there is provided a two-phase stainless steel capable of providing a wide temperature range over which the melt thereof has a suitable fluidity without increasing the pouring temperature and, therefore, capable of easily affording a cast article having a thinner portion.

[0013] Preferably, the specific contents in mass % are: up to 0.08 % of C, not less than 0.5 % but not more than 1.5 % of Si, up to 1.0 % of Mn, not less than 4.0 % but not more than 8.0 % of Ni, not less than 23 % but not more than 27 % of Cr, not less than 2.0 % but not more than 6.0 % of Cu, not less than 0.05 % but not more than 0.3 % of N, and the balance being Fe and unavoidable impurities.

[0014] Further, preferably the two-phase stainless steel has a melting point of not higher than 1,450°C, and being used as a casting material of a cast article comprising a portion having a thickness of 3mm or less.

[0015] It further discloses a cast article of a two-phase stainless steel, comprising the two-phase stainless steel according to any one of the above embodiments.

[0016] Further, it discloses a cast article in the form of a propeller blade for a propulsion unit of a small watercraft, and comprising the two-phase stainless steel according to one of the above embodiments.

[0017] For the method aspect, this objective is solved by a method to manufacture a two-phase stainless steel having a ferrite phase and an austenite phase, by preparing a melt including specific contents of C, Si, Mn, Ni, Cr, Cu, N and

Fe, and substantially free of Mo addition, and adjusting an area ratio of the ferrite phase in a range between 20% and 60%.

[0018] Preferably, the melt is prepared with the specific contents in mass %: up to 0.08 % of C, not less than 0.5 % but not more than 1.5 % of Si, up to 1.0 % of Mn, not less than 4.0 % but not more than 8.0 % of Ni, not less than 23 % but not more than 27 % of Cr, not less than 2.0 % but not more than 6.0 % of Cu, not less than 0.05 % but not more than 0.3 % of N, and the balance being Fe and unavoidable impurities.

[0019] In the following, the present invention is explained in greater detail with respect to several embodiments thereof in conjunction with the accompanying drawings, wherein:

FIG.1 is a plan view, schematically illustrating a propeller of a small watercraft, and

FIG. 2 is a phase diagram, schematically showing phase constitution as a function of the Ni equivalent vs. Cr equivalent.

Description of Reference Numerals:

[0020]

10	propeller
11	central base section
12	blade (thin portion)

[0021] An embodiment of the present teaching will be hereinafter described.

[0022] FIG. 1 shows a propeller, as a cast article of an embodiment, for a propulsion unit of a small watercraft.

[0023] Reference numeral 10 denotes a propeller formed of a certain two-phase stainless steel. The propeller has a central base section 11 and a pair of blades 12 extending in radial, opposite directions from the base section 11, which are formed in one body. Each blade 12 includes its wide surface portion preferably having a thickness of 3 mm or less, more preferably 2 mm or less.

[0024] The propeller 10 is formed using a casting mold including two hollow potions, one for forming the central base portion 11 and the others for forming casting blades 12. The two hollow portions are in communication with each other. The melt to be poured into the casting mold includes constituent elements whose amounts are selected to obtain a specified two-phase stainless steel of the propeller formed. The propeller 10 is formed by pouring the melt into the casting mold at a pouring temperature of for example 1,550 to 1,650°C and then leaving as it is for heat release.

[0025] The two-phase stainless steel as a material configuring such propeller 10 comprises C, Si, Mn, Ni, Cr, Cu, N and the balance. The balance includes Fe and unavoidable impurities. Thus, the stainless steel is substantially free of expensive Mo. Yet, the two-phase stainless steel has a ferrite phase and an austenite phase and a reduced melting point.

[0026] The reason for selecting the contents of constitutional elements are as follows:

[0027] Carbon (C) is highly effective to form a stable austenite phase and to improve the strength of the two-phase stainless steel. If the C content is excessively high, however, chromium carbide is apt to be formed so that the corrosion resistance of the steel is deteriorated and, further, the steel becomes brittle. Additionally, as the C content increases, the melting point of the steel decreases but the strength of the steel is adversely affected. Accordingly, the C content is preferable to be low, i.e. up to 0.08 mass % in this case.

[0028] Silicon (Si) is a deoxidizer and is somewhat effective to stabilize the ferrite phase. Further, the melting point of the steel decreases as an increase of the Si content. Since Mo which is a ferrite-stabilizing element is not used in the present teaching, the use of Si in a relatively large amount is desired. Accordingly, the Si content is preferable to be high, i.e. not less than 0.5 mass % but not more than 1.5 mass %.

[0029] Manganese (Mn) is a deoxidizer and, as well as Ni, contributes to an increase of solid solution of N in the two-phase stainless steel. Mn is also less effective to stabilize the austenite phase. The melting point of the stainless steel decreases with an increase of the Mn content. The use of Mn in an excessive amount, however, adversely affects corrosion resistance such as pitching corrosion resistance. Accordingly, the Mn content is preferably up to 1.0 mass %.

[0030] Nickel (Ni) improves mechanical properties and moldability, contributes to maintain corrosion resistance and stabilize an austenite phase. Ni also has a small influence upon the melting point of the stainless steel although depending upon the amount thereof. Because Mo which is a ferrite-stabilizing element is not used in the present teaching, Ni which is an austenite stabilizing element and has small influence upon the melting point is not desired to be used in a large amount. Accordingly, the Ni content is preferable to be low, i.e. not less than 4.0 mass % but not more than 8.0 mass %.

[0031] Chromium (Cr) a main component which contributes to impart corrosion resistance to the two-phase stainless steel and stabilizes a ferrite phase. The higher the Cr content, the better is the corrosion resistance due to an improved stability of a passive film. Cr also has a small influence upon the melting point of the steel although depending upon the amount thereof. Because Mo which is a ferrite-stabilizing element and contributes to corrosion resistance is not used in the present teaching, Cr which is a ferrite stabilizing element and contributes to improve corrosion resistance is desired to be used in a large amount. However, too large an amount of Cr adversely affects the mechanical properties and moldability. Accordingly, the Cr content is preferably not less than 23 mass % but not more than 27 mass %.

[0032] Copper (Cu) imparts corrosion resistance to the two-phase stainless steel. The melting point of the steel can be reduced by increasing the Cu content. Since Mo which contributes to improve corrosion resistance is not used in the present teaching, the Cu content is desired to be high. However, too high a Cu content causes brittleness of the steel. Accordingly, the Cu content is preferably not less than 2.0 mass % but not more than 6.0 mass %.

[0033] Nitrogen (N) can increase the strength of the two-phase stainless steel even in a small amount and is highly effective to stabilize an austenite phase. The N content has little influence upon the melting point of the steel. Too large an amount of N is undesirable because of the precipitation of nitrides. Accordingly, the N content is preferably not less than 0.05 mass % but not more than 0.3 mass %.

[0034] The balance of the two-phase stainless steel is Fe and unavoidable impurities such as P and S. Such impurities may possibly include Mo. As long as the amount of impurity Mo is not more than 0.3 mass %, it may be further removed, or may be used as it is without removal, because the Mo content, which is an unavoidable impurity, is very small.

[0035] To obtain the two-phase stainless of the present teaching, the contents of the components described above are selected within the respective ranges thereof to adjust the area ratio of the ferrite phase and the austenite phase. The area ratio of the ferrite phase should be not less than 20 % but not more than 60 % in order for the stainless steel to exhibit well balanced corrosion resistance, particularly pitting corrosion resistance and mechanical strength.

[0036] The area ratio of the ferrite phase varies depending on cooling rate and the like production conditions, but may be suitably controlled by adjustment of mixing proportions of the elements of the two-phase stainless steel in terms of the Cr equivalent (ferrite forming elements) and Ni equivalent (austenite forming elements) which may be expressed by the following formulas (1) and (2), for example:

Formula 1

[0037]

$$\text{Cr equivalent} = \%\text{Cr} + \%\text{Mo}\,{}^{*} + 1.5\times\%\text{Si} + 0.5\times\%\text{Nb} \qquad (1)$$

$$\text{Ni equivalent} = \%\text{Ni} + 30\times\%\text{C} + 0.5\times\%\text{Mn} + 30\times\%\text{N} \qquad (2)$$

wherein individual %elements show the contents of these elements in terms of mass %, and %Nb is taken into account only when it is present.

[0038] FIG. 2 shows a schematic phase diagram which gives the area ratio of the ferrite phase as a function of the nickel equivalent vs. the chromium equivalent. In the present teaching, the proportion of constituent elements is adjusted so that the Cr equivalent and Ni equivalent fall within the region S where the area ratio of the ferrite phase is not less than 20 % but not more than 60 %. Because the strength is apt to be reduced due to excessive small area ratio of the ferrite phase, wile the corrosion resistance is apt to be deteriorated due to excessive large area ratio of the ferrite phase.

[0039] Further, the area ratios of the ferrite phase and the austenite ratios are adjusted in such a manner described above and the contents of the component elements also described above are adjusted so that the melting point of the two-phase stainless steel of the embodiment is adjusted preferably to a 1,450°C or lower, more preferably 1,430°C or lower. The melting point is preferable to be low as far as possible. Because, if it is determined to be excessively high then the temperature of the melt must be determined to be higher. The fluidity of the melt would be otherwise apt to be reduced, causing difficulty of forming the thin portion.

[0040] As the two-phase stainless steel described above: contains specific content of C, Si, Mn, Ni, Cr, Cu, N and Fe, and unavoidable impurities; has the ferrite phase and the austenite phase; and has an area ratio of the ferrite phase in a range between 20% and 60%. Therefore, the two-phase stainless steel of the present teaching can show well-balanced mechanical strength and corrosion resistance even though Mo is not added thereto. For the propeller 10 brought in contact with water or seawater, a two-phase stainless steel can be provided which is inexpensive and durable in practical use with a less number of kinds of component elements.

[0041] Also, as this two-phase stainless steel has a melting point of 1450°C or less, a wider range of the temperature in which the melt can flow is easily secured without a higher pouring temperature being determined. The thermal load applied to the casting mold is therefore not increased and the fluidity of the melt is improved. As a result, molding defects hardly occur in the blades 12 even though the blades 12 have a thin portion of 3mm or less thick.

[0042] The propeller 10 of such two-phase stainless steel can be fabricated inexpensively because of less kinds of component elements and has a well fluidity of the melt thereof for avoiding casting defects of the blades 12, resulting in easy production thereof. A mechanical strength and a corrosion resistance sufficient to resist against stresses generated and applied corresponding to a propulsive force in normal temperature water and seawater can be secured.

Example

[0043] The following examples and comparative examples will be described and illustrated.

[0044] Stainless steels containing components shown in Table 1 and the balance containing Fe and unavoidable impurities were prepared and determined for their liquid phase line temperatures (as melting points) and area ratios of the ferrite phase (α phase) and austenite phase (γ phase) by actual measurement and by simulation.

[0045] The results are shown in Table 1.

[Table 1]

	C	Si	Mn	Ni	Cr	Cu	Mo	N	Liquid phase line temperature (°C)	α phase	γ phase
Comparative Example 1	0.054	0.7	0.58	8.87	22.98	0.15	3.31	0.13	1453	-	-
Comparative Example 2	0.05	0.8	0.8	7	25.00	2.5	3.00	0.15	1425	41.8	57
Example 1	0.05	0.8	0.8	7	25.00	2.5	0	0.15	1425	24.4	74.6
Example 2	0.05	0.8	0.8	7	25.00	4	0	0.15	1404	30.2	65.2
Example 3	0.05	1.2	0.8	6	25.00	4	0	0.15	1409	40.4	54.7
Example 4	0.05	1.2	0.8	6	25.00	4	0	0.2	1405	34.4	60.4
Example 5	0.05	1.2	0.8	6	25.00	4	0	0.3	1399	28.8	65.8
Example 6	0.050	1.17	0.82	5.59	25.10	4.00	0	0.15	-	50	50
Note 1: %mass for element Note 2: measurement value as to Comparative Example 1 and Example 1											

[Strength test]

[0046] Example 6 and Comparative Example 1 were tested for tensile test and impact test for test pieces thereof as follows.

[0047] Using the test pieces having the same shape, a tensile test was carried out by the metallic material tensile test in accordance with JIS Z2371.

[0048] Using the test pieces having the same shape, an impact test was carried out by metallic material impact test in accordance with JIS Z2371.

[0049] The test results are summarized in Table 2.

[Table 2]

	Tensile strength (MPa)	0.2 % Proof strength (MPa)	Elongation after fracture (%)	Impact strength (J/cm^2)
Comparative Example 1	654	430	12.7	66.4
Example 6	734	450	11.3	105

[0050] As is evident from the results shown in Table 2, the Mo-free two-phase stainless steel of Example 6 has equal or higher tensile strength and impact strength as compared with the Mo-containing stainless steel of Comparative Example 1.

Casting test

[0051] Using the stainless steels of Example 6 and Comparative Example 1, propellers as shown in FIG. 1 were prepared by casting.

[0052] The minimum thickness of the blades 12 of the propeller 10 was 1.6 mm.

[0053] As a result, a good cast propeller could be obtained using the stainless steel of Example 6. On the other hand, due to a high melting point, the blades 12 made of the stainless steel of Comparative Example 1 had casting defects when the same pouring temperature was used to thereby reduce the temperature range. It was revealed that the stainless steel of Example 6 was able to give a thin cast article more easily than that of Comparative Example 1.

Corrosion resistance test

[0054] The propellers 10 made of the stainless steels of Example 6 and Comparative Example 1 were each subjected to a corrosion test.

[0055] An aqueous brine solution spray test as the corrosion test was carried out under conditions in accordance with JIS Z 2371. Thus a 5 % by weight aqueous brine solution having its temperature of 35°C was sprayed over the test piece. The test piece was then allowed to stand for 4 days to check rust formation with naked eyes.

[0056] No rust was observed on surfaces of the test pieces of Example 6 and Comparative Example 1. Thus, it was revealed that the stainless steel of Example 6 has corrosion resistance similar to the stainless steel Comparative Example 1.

[0057] The description above discloses, amongst others, an embodiment of a two-phase stainless steel comprising Fe as a major component and further containing C, Si, Mn, Ni, Cr, Cu, N and unavoidable impurities, and comprising a ferrite phase and an austenite phase with an area ratio of the ferrite phase being not less than 20 % but not more than 60 % (first aspect).

[0058] Preferably, there is disclosed an embodiment of a two-phase stainless steel comprising, in mass %: up to 0.08 % of C, not less than 0.5 % but not more than 1.5 % of Si, up to 1.0 % of Mn, not less than 4.0 % but not more than 8.0 % of Ni, not less than 23 % but not more than 27 % of Cr, not less than 2.0 % but not more than 6.0 % of Cu, not less than 0.05 % but not more than 0.3 % of N, and the balance being Fe and unavoidable impurities, and comprising a ferrite phase and an austenite phase with an area ratio of the ferrite phase being not less than 20 % but not more than 60 % (second aspect).

[0059] Further, preferably there is disclosed a two-phase stainless steel having a melting point of not higher than 1,450°C, and being used as a casting material of a cast article comprising a portion having a thickness of 3mm or less (third aspect).

[0060] Further, preferably there is disclosed a cast article of a two-phase stainless steel, comprising the two-phase stainless steel according to any one of the first to third aspects (fourth aspect).

[0061] Further, there is disclosed an embodiment of a cast article in the form of a propeller blade for a propulsion unit of a small watercraft, comprising the two-phase stainless steel according to the third aspect (fifth aspect).

[0062] To solve the problems mentioned above, the description above discloses a two-phase stainless steel of the first aspect comprising Fe as a major component and further containing C, Si, Mn, Ni, Cr, Cu, N and unavoidable impurities, and comprising a ferrite phase and an austenite phase with an area ratio of the ferrite phase being not less than 20 % but not more than 60 %.

[0063] Further, it discloses a two-phase stainless steel of the second aspect comprising, in mass %: up to 0.08 % of C, not less than 0.5 % but not more than 1.5 % of Si, up to 1.0 % of Mn, not less than 4.0 % but not more than 8.0 % of Ni, not less than 23 % but not more than 27 % of Cr, not less than 2.0 % but not more than 6.0 % of Cu, not less than 0.05 % but not more than 0.3 % of N, and the balance being Fe and unavoidable impurities, and comprising a ferrite phase and an austenite phase with an area ratio of the ferrite phase being not less than 20 % but not more than 60 %.

[0064] Further, it discloses a two-phase stainless steel of the third aspect having a melting point of not higher than 1,450°C, and being used as a casting material of a cast article comprising a portion having a thickness of 3mm or less.

[0065] Further, it discloses a cast article of a two-phase stainless steel of the fourth aspect comprising the two-phase stainless steel according to any one of the first to third aspects.

[0066] Further, it discloses a cast article in the form of a propeller blade for a propulsion unit of a small watercraft of the fifth aspect comprising the two-phase stainless steel according to the third aspect.

Effect

[0067] As the two-phase stainless steel according to the first or second aspect: contains Fe as a major component, and C, Si, Mn, Ni, Cr, Cu, N and unavoidable impurities; has the ferrite phase and the austenite phase; and has an area ratio of the ferrite phase in a range between 20% and 60% that is obtained by adjustment of contents of the component elements, Therefore, the two-phase stainless steel of the present teaching can show well-balanced mechanical strength and corrosion resistance even though Mo is not added thereto. For the propeller 10 brought in contact with water or seawater, a two-phase stainless steel can be provided which is inexpensive and durable in practical use with a less number of kinds of component elements.

[0068] Also, as the two-phase stainless steel according to the third aspect having a melting point of 1450°C or less is used as a material of cast article including a thin portion having a thickness of 3 mm or less, a wider range of the temperature in which the melt can flow is easily secured without a higher pouring temperature being determined. The thermal load applied to the casting mold is therefore not increased and the fluidity of the melt is improved. As a result, molding defects hardly occur in the blades 12 even though the blades 12 have a thin portion of 3mm or less thick.
[0069] As the two-phase stainless cast article of the fourth aspect comprises the Mo-free, 2-phase stainless steel according to claim 1 or 2, it is given corrosion resistance and mechanical strength enough to be used in contact with water and seawater.
[0070] The two-phase stainless steel cast article of the fifth aspect is directed to a propeller having blades and made of two-phase stainless steel according to the first or second aspect, for a propulsion unit of a small watercraft, the blades having widely extending thin portions. The propeller 10 of such two-phase stainless steel can be fabricated with well fluidity of the melt thereof for avoiding casting defects of the blades 12, resulting in easy production. A mechanical strength and a corrosion resistance enough to resist against stresses generated and applied corresponding to a propulsive force in water and seawater of normal temperature can be secured. Accordingly, a propeller can be provided, which is easily fabricated and given corrosion resistance and mechanical strength enough to be used in practical use.
[0071] The description, in particular discloses, in order to provide an inexpensive, Mo-free, ferrite-austenite two-phase stainless steel having satisfactory mechanical strength and corrosion resistance in practical use, an embodiment of the stainless steel which has a ferrite phase area ratio of 20 to 60 % and a composition containing, in mass %, not more than 0.08 % of C, 0. 5 to 1.5 % of Si, not more than 1.0 % of Mn, 4.0 to 8.0 % of Ni, 23 to 27 % of Cr, 2.0 to 6.0 % of Cu, 0.05 to 0.3 % of N, and the balance being Fe and unavoidable impurities.

Claims

1. Two-phase stainless steel having a ferrite phase and an austenite phase, **characterized by** containing specific contents of C, Si, Mn, Ni, Cr, Cu, N and Fe, and unavoidable impurities, and having an area ratio of the ferrite phase in a range between 20% and 60%.

2. Two-phase stainless steel according to claim 1, **characterized in that** the specific contents in mass % are:

   up to 0.08 % of C,
   not less than 0.5 % but not more than 1.5 % of Si,
   up to 1.0% of Mn,
   not less than 4.0 % but not more than 8.0 % of Ni,
   not less than 23 % but not more than 27 % of Cr,
   not less than 2.0 % but not more than 6.0 % of Cu,
   not less than 0.05 % but not more than 0.3 % of N, and
   the balance being Fe and unavoidable impurities.

3. Two-phase stainless steel according to claim 1 or 2, **characterized by** having a melting point of not higher than 1,450°C, and **characterized by** being used as a casting material of a cast article comprising a portion having a thickness of 3mm or less.

4. Cast article of a two-phase stainless steel, **characterized by** comprising the two-phase stainless steel according to any one of claims 1 to 3.

5. Cast article according to claim 4, in the form of a propeller blade for a propulsion unit of a small watercraft, and being **characterized by** comprising the two-phase stainless steel according to claim 3.

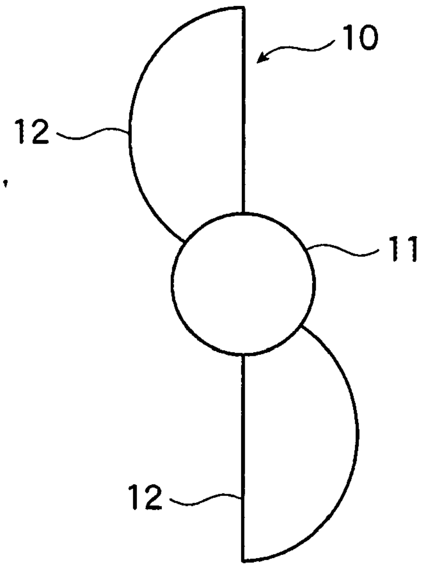
6. Method to manufacture a two-phase stainless steel having a ferrite phase and an austenite phase, by preparing a melt including specific contents of C, Si, Mn, Ni, Cr, Cu, N and Fe, and substantially free of Mo addition, and adjusting an area ratio of the ferrite phase in a range between 20% and 60%.

7. Method according to claim 6, **characterized in that** the melt is prepared with the specific contents in mass %:

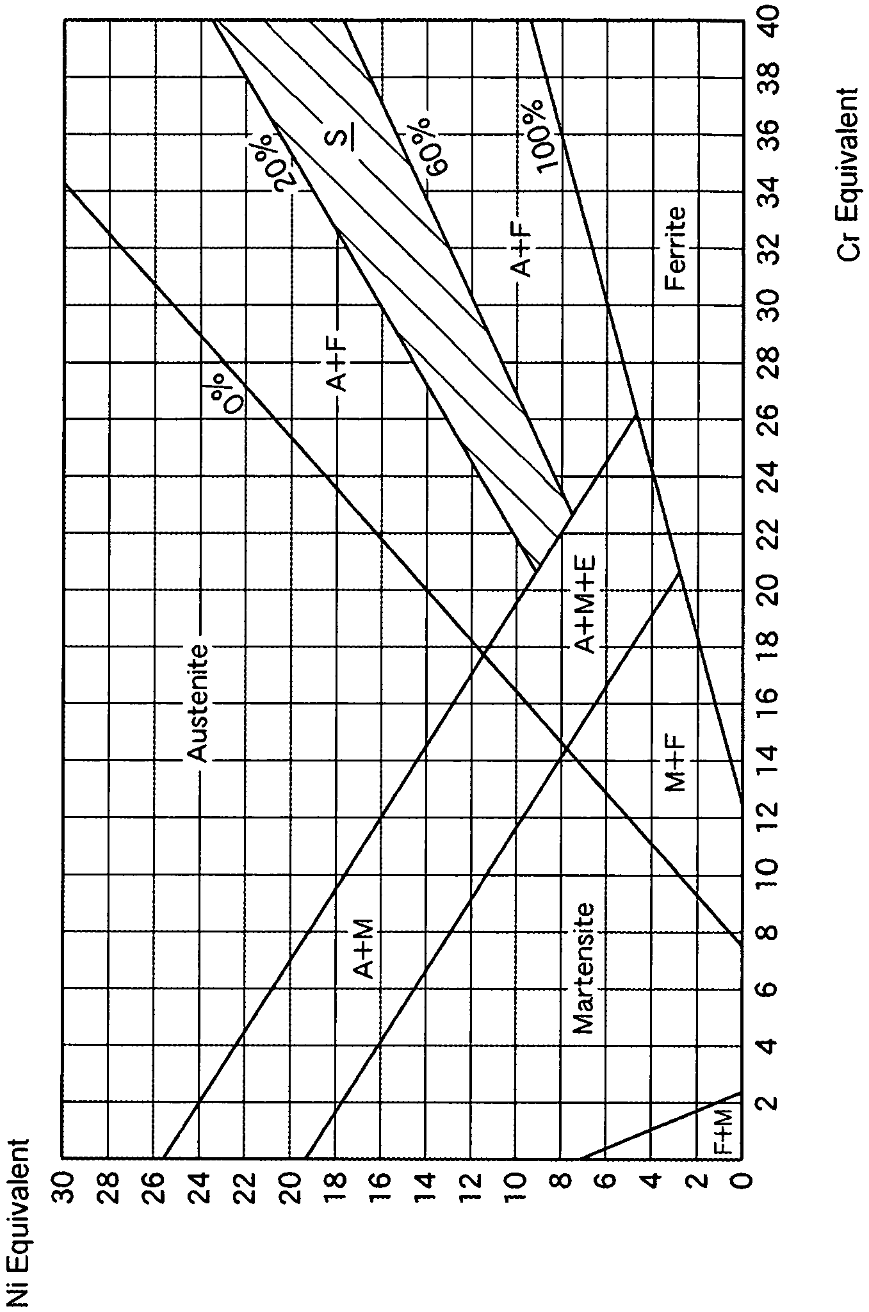
   up to 0.08 % of C,
   not less than 0.5 % but not more than 1.5 % of Si,
   up to 1.0 % of Mn,

not less than 4.0 % but not more than 8.0 % of Ni,
not less than 23 % but not more than 27 % of Cr,
not less than 2.0 % but not more than 6.0 % of Cu,
not less than 0.05 % but not more than 0.3 % of N, and
the balance being Fe and unavoidable impurities.

[FIG. 1]



[FIG. 2]


Ni Equivalent
Cr Equivalent
Austenite
Martensite
Ferrite
A+M
A+F
A+F
M+F
A+M+E
F+M
0%
20%
60%
100%
S
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 00 1223

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 0 261 345 A (SANDUSKY FOUNDRY & MACHINE CO [US]) 30 March 1988 (1988-03-30) * figures 5,6; tables I-III * -----	1-7	INV. C22C38/42
X	US 4 612 069 A (RAINGER CHARLES W [US] ET AL) 16 September 1986 (1986-09-16) * claims 1,2; tables I-IV * -----	1-7	
A	US 6 033 497 A (RYAN EDWARD R [US] ET AL) 7 March 2000 (2000-03-07) * claims 1-9 * -----	1-7	
A	US 5 672 215 A (AZUMA SHIGEKI [JP] ET AL) 30 September 1997 (1997-09-30) * claims 1-19; figures 1-5 * -----	1-7	
A	US 4 798 635 A (BERNHARDSSON SVEN-OLOV [SE] ET AL) 17 January 1989 (1989-01-17) * claims 1-25; figures 1,2; tables I-IV * -----	1-7	
			TECHNICAL FIELDS SEARCHED (IPC)
			C22C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 April 2008	Catana, Cosmin

CATEGORY OF CITED DOCUMENTS

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28-04-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0261345 A	30-03-1988	BR 8704466 A	19-04-1988
		CA 1317131 C	04-05-1993
		DE 3769055 D1	08-05-1991
		FI 873633 A	01-03-1988
		JP 1739882 C	15-03-1993
		JP 3080863 B	26-12-1991
		JP 63060261 A	16-03-1988
US 4612069 A	16-09-1986	NONE	
US 6033497 A	07-03-2000	BR 9811763 A	29-08-2000
		CA 2297670 A1	18-03-1999
		CN 1334356 A	06-02-2002
		CN 1269840 A	11-10-2000
		EP 1019549 A1	19-07-2000
		JP 2002511525 T	16-04-2002
		WO 9913114 A1	18-03-1999
US 5672215 A	30-09-1997	EP 0750053 A1	27-12-1996
		WO 9618751 A1	20-06-1996
		JP 3271262 B2	02-04-2002
US 4798635 A	17-01-1989	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
		EP 0156778 A2	02-10-1985
		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
		ZA 8502013 A	27-11-1985

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

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Patent documents cited in the description

- JP 3270498 B **[0005]**
- JP H09302446 A **[0005] [0007]**