**ABSTRACT**

A Cr—Mn—N austenitic stainless steel, in which moderate manganese (Mn) and nitrogen (N) are essentially substituted for the costly nickel to produce a novel Cr—Mn—N steel, is provided, whereby reducing the cost of materials while maintaining the original physical and mechanical properties. The composition thereof includes by weight: 0.005% to 0.08% carbon, 0.3% to 0.9% silicon, 12.1% to 14.8% manganese, 0.001% to 0.04% phosphorus, 0.001% to 0.03% sulfur, 16% to 19% chromium, 0.5% to 1.8% nickel, 0.2% to 0.45% nitrogen, 0.001% to 0.3% molybdenum, 0.001% to 0.3% copper, and trace elements unavoidable in most manufacturing processes.
Cr equivalent = %Cr + %Mo + 1.5*%Si + 0.5*%Cb

Fig. 1
Fig. 2A

casting condition *200

Fig. 2B

casting condition *200
CR-MN-N AUSTENITIC STAINLESS STEEL

BACKGROUND OF THE INVENTION

[0001] Field of the Invention

[0002] The present invention relates to an austenitic stainless steel, in particular to an austenitic stainless steel in which manganese and nitrogen are used in substitution for nickel.

[0003] Related Art

[0004] The ordinary stainless steel has the properties of the pleasing white luster on the surface and the stainless tendency. There is a variety of stainless steel that is popular among the consumers and widely used in, for example, stainless steel kitchenware, water tank, mechanical components, sports gear, aerospace materials, medical instruments, and 3C industry etc., in which the most widely and frequently used is the 304 stainless steel. The standard composition thereof includes 18% chromium plus 8% nickel i.e., the commonly called 18-8 stainless steel. The characteristics of such stainless steel include good mechanical properties, magnetism free, stable metallographic grain structure unable to be changed by heat treatment, good durability, good processability, and superior corrosion resistance due to the higher content of nickel. However, the 304 stainless steel is at a stiff price because of the worldwide shortage of nickel caused by war. Accordingly, it is an important issue to reduce the nickel content in the aforementioned Cr—Ni stainless steel and to use other elements in the composition thereof to maintain or even enhance the inherent mechanical properties and corrosion resistance, thereby saving the resource of nickel and reducing the cost of materials.

SUMMARY OF THE INVENTION

[0005] In view of the foregoing, an object of the present invention is to provide a novel steel of single austenitic structure with less nickel, and the corrosion resistance, strength, elongation of which in the marine atmosphere and the acid atmosphere are at the same level as or even better than those of the 304 stainless steel.

[0006] To solve the aforementioned problem, the present invention disposes a technique using moderate manganese (Mn) and nitrogen (N) in substitution for the costly nickel to produce a novel Cr—Mn—N steel, whereby providing a Cr—Mn—N austenitic stainless steel comprising: 0.05% to 0.08% carbon by weight; 0.3% to 0.9% silicon by weight; 12.1% to 14.8% manganese by weight; 0.001% to 0.04% phosphorus by weight; 0.001% to 0.03% sulfur by weight; 16% to 19% chromium by weight; 0.5% to 1.8% nickel by weight; 0.2% to 0.45% nitrogen by weight; 0.001% to 0.3% molybdenum by weight; 0.001% to 0.3% copper by weight; and trace elements unavoidable in most manufacturing processes.

[0007] The effects obtained by practice of the present invention lie in: the present invention employs the formation mechanism of austenitic (or γ) steel, substituting moderate manganese and nitrogen for the costly nickel to produce a novel Cr—Mn—N steel of single austenitic structure, while maintaining the corrosion resistance, strength, elongation thereof in the marine atmosphere and the acid atmosphere at the same level as or even better than those of the 304 stainless steel, so as to achieve the purpose of reducing the cost of materials. The present invention adopts the method of substituting manganese and nitrogen for nickel to produce the pure magnetism-free austenitic stainless steel, the mechanical property UTS of which is approximately 200 MPa higher than that of the 304 stainless steel, the elongation reaches 50%, and the corrosion resistance is equal. And the most important is that the unit price thereof is less than half of the 304 stainless steel. The characteristics of this novel steel include excellent fluidity, superior casting properties, and good resistance to high temperature oxidation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present invention will become more fully understood from the detailed description given herein below for illustration only, and which thus is not limitative of the present invention, and wherein:

[0009] FIG. 1 is a Schaeffler diagram showing the Ni—Cr equivalent of the Cr—Mn—N austenitic stainless steel according to one embodiment of the present invention; and

[0100] FIGS. 2A and 2B are metallographs showing different parts of the Cr—Mn—N austenitic stainless steel according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0111] The contents of the present invention are described in details through specific embodiments with reference to the figures. The reference numerals mentioned in the specification correspond to equivalent reference numerals in the figures.

[0112] The present invention essentially includes a Cr—Mn—N stainless steel of austenitic metallographic structure, which is melted by electric arc furnace or vacuum induction furnace. The composition of the Cr—Mn—N austenitic stainless steel includes by weight: 0.005% to 0.08% carbon; 0.3% to 0.9% silicon; 12.1% to 14.8% manganese; 0.001% to 0.04% phosphorus; 0.001% to 0.03% sulfur; 16% to 19% chromium; 0.5% to 1.8% nickel; 0.2% to 0.45% nitrogen; 0.001% to 0.3% molybdenum; 0.001% to 0.3% copper; and trace elements unavoidable in most manufacturing processes.

[0113] The equations of the composition of the above elements are:

| Ni equivalent= % Ni+30% C+0.5% Mn+30% N |
| Cr equivalent= % Cr+4% Mo+1.5% Si+0.5% Ch |

[0116] Referring to the phase diagram shown in FIG. 1, where the ordinate is Ni equivalent and the abscissa is Cr equivalent, if the point falls in the austenite area according to computation, then the requirements in table 1 are satisfied.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
</tr>
<tr>
<td>Mass Percentage</td>
</tr>
</tbody>
</table>
TABLE 1-continued

<table>
<thead>
<tr>
<th>Composition</th>
<th>% C</th>
<th>% Si</th>
<th>% Mn</th>
<th>% P</th>
<th>% S</th>
<th>% Cr</th>
<th>% Ni</th>
<th>% N</th>
<th>% Mo</th>
<th>% Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>0.002</td>
<td>0.3</td>
<td>12.1</td>
<td>16</td>
<td>0.5</td>
<td>0.1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>0.08</td>
<td>0.9</td>
<td>14.8</td>
<td>19</td>
<td>1.3</td>
<td>0.45</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[0017] Minimum Ni equivalent = 0.5 + 30 × 0.002 + 0.5 × 12.1 + 30 × 0.2 = 12.61
[0018] Maximum Ni equivalent = 1.8 + 30 × 0.08 + 0.5 × 14.8 + 30 × 0.45 = 25.1
[0019] Minimum Cr equivalent = 16 + 0 + 1.5 × 0.3 + 0.5 × 0 = 16.45
[0020] Maximum Cr equivalent = 19 + 0.3 + 1.5 × 0.9 + 0.5 × 0 = 20.65
[0021] The shadowed area in FIG. 1 shows the major austenite composition.
[0022] Composition analysis of the test samples is shown in table 2.

TABLE 2

<table>
<thead>
<tr>
<th>Composition</th>
<th>% C</th>
<th>% Si</th>
<th>% Mn</th>
<th>% P</th>
<th>% S</th>
<th>% Cr</th>
<th>% Ni</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Percent</td>
<td>0.0079</td>
<td>0.65</td>
<td>12.27</td>
<td>17.06</td>
<td>1.68</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[0023] Maximum Ni equivalent = 1.68 + 30 × 0.0079 + 0.5 × 12.27 + 30 × 0.42 = 20.652
[0024] Minimum Cr equivalent = 17.06 + 0 + 1.5 × 0.65 + 0.5 × 0 = 18.035
[0025] Further referring to the phase diagram shown in FIG. 1, the point falls in the austenitic area, which satisfies the requirements.
[0026] The present invention essentially employs manganese and nitrogen in partial or complete substitution for nickel. The characteristics of manganese and nitrogen are analyzed below.
[0027] The influence of manganese on grain structure includes:
[0028] a. The content of manganese should be 2% or less when used as a deoxidizer.
[0029] b. The content of manganese may be up to 20% when used as an alloy element.

[0030] c. The substitution of manganese for nickel increases solubility of nitrogen, achieving the effects of saving nickel and enhancing strength.
[0031] The influence of manganese on mechanical properties includes:
[0032] a. When the content of manganese is 2% or less, hardness is not affected but tensile strength and yield strength decrease.
[0033] b. The high-temperature thermoplasticity of high Ni-Cr γ-S is improved.
[0034] The influence of manganese on corrosion resistance includes:
[0035] MnS inclusion causes decreases in corrosion resistance and interstitial corrodisbility
[0036] The influence of nitrogen on grain structure includes:
[0037] a. Nitrogen dramatically forms and broadens the γ phase area, thereby enhancing the γ stability.
[0038] b. Carbide precipitation is suppressed and the precipitation of a phase is delayed, which benefits the anti-sensitization of intergranular corrosion and toughness of the steel.
[0039] The influence of nitrogen on mechanical properties includes:
[0040] a. By means of solid solution strengthening (which forms interstitial solid solution), strength of the steel considerably increases while plasticity and toughness decrease.
[0041] b. Excess of nitrogen (≥0.84%) results in plastic-brittle transition.
[0042] According to the Schaeffler diagram of the Ni—Cr equivalent in FIG. 1, manganese and nitrogen may partially or completely substitute for nickel in γ stainless steel, whereby enhancing strength and maintaining elongation as that of the 304 stainless steel without changing the structure of the steel.
[0043] Harmful elements such as phosphorus and sulfur tend to be generated by the melted iron in the furnace during smelting, where the content of phosphorus should be controlled under 0.04% or less, and the content of sulfur should be controlled under 0.04% or less.
[0044] The compositions of the embodiments of the present invention and the contrast material are shown in table 3 below.

TABLE 3

<table>
<thead>
<tr>
<th>Specimens</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>N</th>
<th>Mo</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
<td>304 Stainless Steel (Contrast Material)</td>
<td>&lt;0.08</td>
<td>≤0.1</td>
<td>&lt;2.0</td>
<td>≤0.045</td>
<td>≤0.03</td>
<td>17 to 19</td>
<td>8 to 10</td>
<td>/</td>
<td>&lt;0.6</td>
</tr>
<tr>
<td>Embodiment 1</td>
<td>0.0642</td>
<td>0.69</td>
<td>12.43</td>
<td>0.031</td>
<td>0.012</td>
<td>16.87</td>
<td>1.21</td>
<td>0.45</td>
<td>0.026</td>
<td>0.106</td>
</tr>
<tr>
<td>Embodiment 2</td>
<td>0.0547</td>
<td>0.81</td>
<td>13.92</td>
<td>0.01</td>
<td>0.001</td>
<td>16.71</td>
<td>0.82</td>
<td>0.24</td>
<td>0.025</td>
<td>0.104</td>
</tr>
<tr>
<td>Embodiment 3</td>
<td>0.0432</td>
<td>0.85</td>
<td>12.12</td>
<td>0.012</td>
<td>0.005</td>
<td>16.38</td>
<td>0.5</td>
<td>0.35</td>
<td>0.027</td>
<td>0.109</td>
</tr>
</tbody>
</table>
The mechanical properties in the aforementioned embodiments in Table 3 are shown in Table 4 below.

<table>
<thead>
<tr>
<th>Specimens</th>
<th>( \sigma_0 )</th>
<th>( \sigma_1 )</th>
<th>( \delta )</th>
<th>Hardness</th>
<th>( \rho )</th>
<th>Salt Spray Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>304 Stainless Steel</td>
<td>520</td>
<td>206</td>
<td>40-50</td>
<td>( \leq 90 )</td>
<td>( \leq 187 )</td>
<td>7.85</td>
</tr>
<tr>
<td>(Contrast Material)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embodiment 1</td>
<td>700</td>
<td>400</td>
<td>40-50</td>
<td>86-92</td>
<td>( \leq 187 )</td>
<td>7.77</td>
</tr>
<tr>
<td>Embodiment 2</td>
<td>751</td>
<td>425.9</td>
<td>51.5</td>
<td>89</td>
<td>180</td>
<td>7.76</td>
</tr>
<tr>
<td>Embodiment 3</td>
<td>706.4</td>
<td>426.7</td>
<td>47.6</td>
<td>88</td>
<td>175</td>
<td>7.77</td>
</tr>
</tbody>
</table>

Referring to the metallographs of different parts shown in FIGS. 2A and 2B, it is observed that the structure thereof is \( \gamma \) before heat treatment. Therefore, the steel is a completely \( \gamma \) stainless steel.

To sum up, the present invention is not restricted to the particular details described herein. Indeed, those skilled in the art having the benefit of this disclosure will appreciate that many other variations from the foregoing description and drawings may be made within the scope of the present invention. Accordingly, it is the following claims including any amendments thereto that define the scope of the invention.

What is claimed is:

1. A Cr—Mn—N austenitic stainless steel, comprising:
   - 0.005% to 0.08% carbon by weight;
   - 0.3% to 0.9% silicon by weight;
   - 12.1% to 14.8% manganese by weight;
   - 0.001% to 0.04% phosphorus by weight;
   - 0.001% to 0.03% sulfur by weight;
   - 16% to 19% chromium by weight;
   - 0.5% to 1.8% nickel by weight;
   - 0.2% to 0.45% nitrogen by weight;
   - 0.001% to 0.3% molybdenum by weight;
   - 0.001% to 0.3% copper by weight; and trace elements unavoidable in most manufacturing processes.

2. The Cr—Mn—N austenitic stainless steel according to claim 1, comprising:
   - 0.0642% carbon by weight;
   - 0.69% silicon by weight;
   - 12.43% manganese by weight;
   - 0.031% phosphorus by weight;
   - 0.012% sulfur by weight;
   - 16.87% chromium by weight;
   - 1.21% nickel by weight;
   - 0.45% nitrogen by weight;
   - 0.026% molybdenum by weight;
   - 0.106% copper by weight; and trace elements unavoidable in most manufacturing processes.

3. The Cr—Mn—N austenitic stainless steel according to claim 1, comprising:
   - 0.457% carbon by weight;
   - 0.81% silicon by weight;
   - 13.92% manganese by weight;
   - 0.11% phosphorus by weight;
   - 0.001% sulfur by weight;
   - 16.71% chromium by weight;
   - 0.82% nickel by weight;
   - 0.24% nitrogen by weight;
   - 0.025% molybdenum by weight;
   - 0.104% copper by weight; and trace elements unavoidable in most manufacturing processes.

4. The Cr—Mn—N austenitic stainless steel according to claim 1, comprising:
   - 0.432% carbon by weight;
   - 0.85% silicon by weight;
   - 12.12% manganese by weight;
   - 0.012% phosphorus by weight;
   - 0.005% sulfur by weight;
   - 16.38% chromium by weight;
   - 0.5% nickel by weight;
   - 0.35% nitrogen by weight;
   - 0.027% molybdenum by weight;
   - 0.109% copper by weight; and trace elements unavoidable in most manufacturing processes.