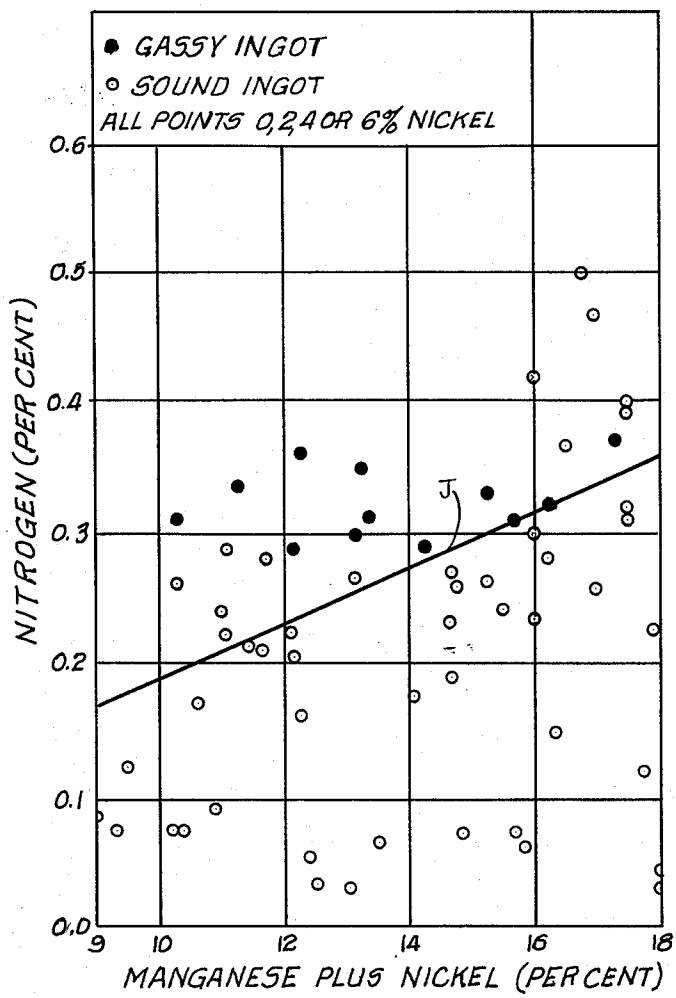
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CORROSION RESISTANT STEELS

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Fig. 1

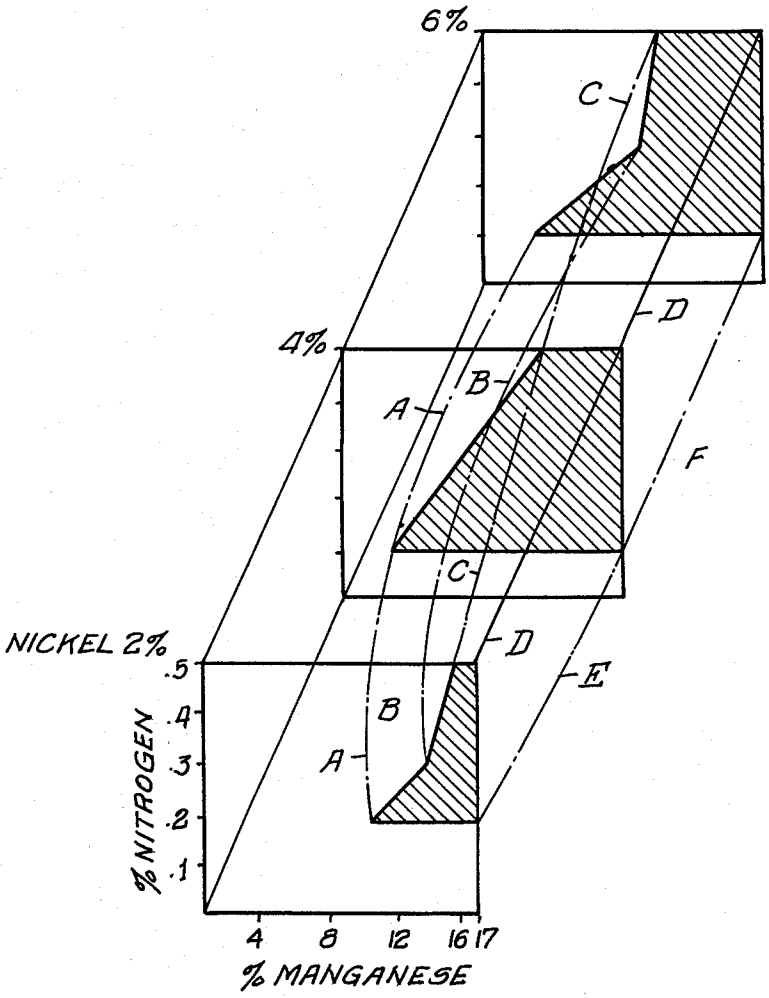


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Fig. 2



United States Patent Office 3,192,041 Patented June 29, 1965

3,192,041

CORROSION RESISTANT STEELS

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Filed Dec. 13, 1962, Ser. No. 244,343
9 Claims. (Cl. 75—130.5)

This application is a continuation-in-part of application Serial No. 45,259, filed July 18, 1960, and now abandoned, which in turn is a continuation-in-part of application Serial No. 699,985, filed December 2, 1957, also abandoned.

This invention relates, as indicated, to corrosion resistant austenitic steels, and more particularly to such steel alloys having reduced nickel contents.

Although the main factor for corrosion resistance of stainless steel alloys is attributed to the exceptional properties of the element chromium, ferritic stainless steels containing this element in various proportions are found to be inferior to the austenitic alloys containing chromium together with the austenite forming element nickel. The use of these austenitic materials, such as exemplified by the 18% by weight chromium and the 8% by weight nickel type steels of the 300 series for corrosion purposes is, however, restricted due to the periodic scarcity of the vital element nickel. There are also indications that additions of other austenitic elements improve the corrosion and/or structural properties.

Addition of nitrogen to the alloy, however, presents problems in the manufacture of "as cast" products that often possess gas holes which are eliminated in mechanically worked products, such as forged articles. For this reason, arbitrary maximum limits on the nitrogen content have been observed in many instances.

It is, therefore, an object of the invention to produce highly austenitic corrosion resistant steels containing the austenite forming element nitrogen. It is a further object of the invention to produce sound, gas-free castings. It is another object of the invention to provide a family of austenitic alloys having reduced amounts of nickel, and which possess properties that are, in certain respects, substantially equal to, or better than, the stainless steels of the 300 series. It is still another object of the invention to provide austenitic alloys with unusually high corrosion resistant properties. Other objects of the invention will appear as the description proceeds.

In the drawings:

FIGURE 1 is a two-dimensional graph illustrating the effect of manganese, nickel, and nitrogen on the soundness of the casting; and

FIGURE 2 is a three-dimensional graph illustrating the proportions of manganese, nickel and nitrogen in the corrosion resistant austenitic steel alloys of the invention.

Briefly stated, the present invention is concerned with an alloy steel comprising from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from 0.16% to about 0.25% by weight of nitrogen, from about 3% to about 6% by weight of nickel, not more than 1% by weight of silicon, not more than 0.12% by weight of carbon, and the balance iron, in which the proportions of manganese, nickel and nitrogen are such that the nitrogen is fully soluble in the alloy in its liquid and solid phase. More specifically, in the alloy steels of the invention, the proportions of manganese, nickel, and nitrogen are within the approximate ranges shown in the drawings.

Pursuant to the present invention it has been discovered that desirable corrosion resistant iron base alloys containing chromium, manganese, nitrogen, and nickel may be produced by maintaining the proportions of nickel, manganese, and nitrogen within certain critical limits.

Referring to FIGURE 1, the maximum nitrogen content is below line J, or less than approximately 0.021 (percent Mn+percent Ni−1) in which percent Mn is the percent by weight of manganese and percent Ni is the percentage by weight of nickel. The combined percentages by weight of manganese plus nickel being in the range of from about 9% to about 18% by weight. Any point within the range of 9% by weight to about 18% by weight of manganese plus nickel and below the maximum nitrogen content is defined by the line J, or 0.021 (percent Mn+percent Ni−1) will yield a sound, non-gassy casting.

Referring to FIGURE 2, the critical limits of the relative amounts of nickel, manganese, and nitrogen can be approximately defined by lines A through H. Lines A, B, C, and D extend between 2% and 6% nickel. On the other hand, line E extends from 2% to 4% nickel, and line F from 4% to 6% nickel. Outside of the critical limits approximately defined by lines A through H, nitrogen becomes at least partially insoluble in the liquid and solid alloy, and the resulting casting is gassy. By maintaining the alloying elements within the ranges set forth above in the brief statement of the invention, and within the limits defined by FIGURE 2, the "as cast" products are sound and possess desirable corrosion resistant properties.

The proportions of manganese and nitrogen selected must alternatively satisfy the limitations imposed by FIGURE 1 or FIGURE 2. Referring to FIGURE 1, by the choice of 4 weight percent for nickel, the manganese weight percent must necessarily be no greater than 12 weight percent and the nitrogen weight percent must be below the maximum nitrogen weight percent as defined by the line J, or below 0.021 (percent Mn+percent Ni−1).

Referring to FIGURE 2, if it is desired to make an alloy of the invention containing 4% by weight of nickel, the proportions of manganese and nitrogen should be selected so as to fall about within the shaded area at 4% nickel in the graph defined by the points lying on lines A through F of FIGURE 2.

One method of using FIGURE 2 in determining the proportions of nickel, manganese, and nitrogen is by first selecting a desired nickel percentage and then finding the cross-section of lines A through F at the selected amount of nickel. The cross-section is found by a plane at right angles to the desired nickel percentage axis intersecting the lines A through F. The points when connected by lines determine the area in which a balance of manganese and nitrogen will produce the alloys of the invention. In the drawings, typical cross-sections are illustrated at 2%, 4%, 6% and 8% nickel by the shaded areas. Thus, if it is desired to make an alloy of the invention containing 3% by weight of nickel, the proportions of manganese and nitrogen should be selected, so as to fall within the shaded area at 3% nickel defined by lines A, B, C, D, and E.

The following table gives the composition of alloys illustrative of the invention:

Example No.	Cr	Ni	Mn	N	C	Si	Mg	Mo	S	P
1	17.85	4.17	8.00	.17	.08	.42	.01	.01	.009	.008
2	18.43	4.09	7.65	.22	.08	.42	.01	.01	.01	.008
3	18.04	4.09	10.55	.19	.07	.44	.01	.01	.01	.008
4	18.17	4.01	11.22	.26	.08	.42	.01	.01	.01	.008
5	18.39	4.17	11.60	.37	.10	.40	.01	.01	.01	.008
6	18.20	4.17	13.30	.23	.08	.47	.01	.01	.011	.008
7	18.39	3.85	14.60	.32	.08	.42	.01	.01	.01	.008
8	18.26	3.85	13.65	.404	.09	.49	.01	.01	.011	.008
9	17.33	4.01	15.15	.20	.08	.42	.01	.01	.01	.008
10	18.40	4.17	16.75	.336	.10	.42	.01	.01	.008	.008
11	17.64	6.38	8.30	.232	.07	.42	.01	.01	.007	.008
12	17.94	6.36	7.35	.266	.08	.40	.01	.01	.008	.008
13	17.47	6.21	12.00	.137	.06	.42	.01	.01	.007	.008
14	18.18	6.52	11.80	.369	.07	.42	.01	.01	.009	.008
15	17.91	5.89	14	.273	.06	.42	.01	.01	.009	.009
16	17.74	6.21	14.65	.449	.07	.40	.01	.03	.008	.008
17	17.91	5.97	14.10	.154	.10	.42	.01	.01	.008	.009
18	18.21	6.21	16.80	.314	.07	.40	.01	.01	.008	.009

It will be understood by the skilled metallurgist that elements, such as carbon, silicon, molybdenum, and the like, can be included in beneficial amounts, as long as they do not upset the balance producing the austenitic alloys of the invention.

Heat treatment is necessary for reducing the amounts of any of the undesirable constituents which may be present in the alloy of the invention as cast. The heat treatment step is carried out by heating to solutionizing temperatures followed by rapid cooling. In conventional practice, the heat treatment is carried out by heating the casting to a temperature within the range from about 1950° F. to about 2200° F., followed by an air, oil, or water quench.

If gassy castings are used to make rolled, forged, and extruded products, the porosity may be eliminated during subsequent hot-working operations. However, in manufacturing shaped castings having the same general configuration of the final product of ultimate use, the production of gas-free, sound castings is essential, since there is no opportunity to close the porosity by working the metal.

In making shaped castings having the same general configuration of the final product of ultimate use, the alloy in its liquid phase is introduced into a shaped, green-sand mold, and allowed to cool. The mold shape determines the final general configuration of the product for the product's ultimate use, although there may be, and usually are, subsequent machining or grinding operations. Thus, because the steel alloy composition of the present invention forms sound, gas-free castings, it is uniquely applicable to the direct production of shaped steel castings.

By definition herein, "shaped castings" specifically exclude ingots, since these forms are for subsequent operations, such as rolling or forging, which are not of the general configuration of the final product of ultimate use. Shaped castings ordinarily possess recesses, or flanges. Often they are hollow. Examples include pressure vessel parts and valve parts, such as valve bodies, valve stems and the like.

The alloy steels of the invention are highly austenitic. Special preference is given to the fully austenitic form, although in some instances it is desirable that the alloy be slightly ferritic and largely austenitic; for example, for welding operations it may be advantageous to have ferrite present in small amounts, such as, not more than 5% by weight.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We, therefore, particularly point out and distinctly claim as our invention:

1. In a process for manufacturing shaped metal castings the steps which comprise: preparing an austenitic ferrous base metal alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from 0.16% to about 0.25% by weight of nitrogen and the balance essentially iron, with the maximum nitrogen content being approximately less than:

$$\text{Percent N} = 0.021\ (\text{Percent Mn} + \text{Percent Ni} - 1)$$

in which percent N is the percentage by weight of nitrogen, percent Mn is the percentage by weight of manganese, and percent Ni is the percentage by weight of nickel, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of the final product of ultimate use; and allowing the melt to cool directly into a casting shaped to the general configuration of the final product of ultimate use.

2. In a process for manufacturing shaped metal castings having recesses and flanges, the steps which comprise: preparing an austenitic ferrous base metal alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from 0.16% to about 0.25% by weight of nitrogen and the balance essentially iron, in which the relative amounts of nickel, manganese, and nitrogen are approximately within the volume described by lines A through F in FIGURE 2 of the accompanying drawings, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of the final product of ultimate use; having recesses and flanges; and allowing the melt to cool directly into a casting shaped to the general configuration of the final product of ultimate use.

3. In a process for manufacturing shaped metal castings having recesses and flanges, the steps which comprise: preparing an alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except for residual impurities usually present in such steel, and the maximum nitrogen content being less than approximately:

$$\text{percent N} = 0.021\ (\text{percent Mn} + \text{percent Ni} - 1)$$

in which percent N is the percentage by weight of nitrogen, percent Mn is the percentage by weight of manganese, and percent Ni is the percentage by weight of nickel, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of the final product of ultimate use having recesses and flanges; and allowing the melt to cool directly into a casting shaped to the general configuration of the final product of ultimate use.

4. In a process for manufacturing pressure vessels, the steps which comprise: preparing an alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except for residual impurities usually present in such steel, and the maximum nitrogen content being less than approximately:

$$\text{percent N} = 0.021\ (\text{percent Mn} + \text{percent Ni} - 1)$$

in which percent N is the percentage by weight of nitrogen, percent Mn is the percentage by weight of manganese, and percent Ni is the percentage by weight of nickel, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of a pressure vessel casting; and allowing the melt to cool directly into a casting shaped to the general configuration of the pressure vessel.

5. In a process for manufacturing pressure vessels, the steps which comprise: preparing an alloy steel melt consisting essentially of about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except for residual impurities usually present in such steel, in which the relative amounts of nickel, manganese, and nitrogen are approximately within the volume described by lines A through F in FIGURE 2 of the accompanying drawings, said alloy steel ranging from being fully austenitic to being largely austenitic and

slightly ferritic; introducing said melt into a shaped mold having the same general configuration of a pressure vessel; and allowing the melt to cool directly into a pressure vessel casting.

6. In a process for manufacturing hollow body castings the steps which comprise: preparing an alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except for residual impurities usually present in such steel, and the maximum nitrogen content being less than approximately:

percent N=0.021 (percent Mn+percent Ni—1)

in which percent N is the percentage by weight of nitrogen, in which percent Mn is the percentage by weight of manganese, and percent Ni is the percentage by weight of nickel, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of a hollow body; and allowing the melt to cool directly into a hollow body casting.

7. In a process for manufacturing hollow body castings the steps which comprise: preparing an alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except for residual impurities usually present in such steel, in which the relative amounts of nickel, manganese, and nitrogen are approximately within the volume described by lines A through F in FIGURE 2 of the accompanying drawings, said alloy steel ranging from being fully austenitic to being largely austenic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of a hollow body; and allowing the melt to cool directly into a hollow body casting.

8. In a process for manufacturing shaped metal castings the steps which comprise: preparing an austenitic ferrous base metal alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, from 6% to about 12% by weight of manganese, from about 3% to about 6% by weight nickel, from about 0.16% to about 0.25% by weight of nitrogen, not more than about 1% by weight silicon, not more than about 0.12% carbon, and the balance essentially iron, except

for residual impurities usually present in such steel, the combined percentages by weight of manganese plus nickel being in the range of from about 4% by weight to about 24% by weight, and the maximum nitrogen content being less than approximately line J in FIGURE 1 of the accompanying drawings, in which the relative amounts of nickel, manganese, and nitrogen are approximately within the volume described by lines A through F in FIGURE 2 of the accompanying drawings, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of the final product of ultimate use; and allowing the melt to cool directly into a casting shaped to the general configuration of the final product of ultimate use.

9. In a process for manufacturing shaped metal casting the steps which comprise: preparing an austenitic ferrous base metal alloy steel melt consisting essentially of from about 18% to about 21% by weight of chromium, 6% to about 12% by weight of manganese, from about 2% to about 8% by weight nickel, from about 0.02% to about 0.5% by weight of nitrogen, with the maximum nitrogen and the balance essentially iron is less than approximately the following in the range of combined percentages by weight of manganese plus nickel from about 4% to about 18%:

percent N=0.021 (percent Mn+percent Ni—1)

in which percent N is the percentage by weight of nitrogen, in which percent Mn is the percentage by weight of manganese, and percent Ni is the percentage by weight of nickel, in which the relative amounts of nickel, manganese, and nitrogen are approximately within the volume described by lines A through F in FIGURE 2 of the accaccompanying drawings, said alloy steel ranging from being fully austenitic to being largely austenitic and slightly ferritic; introducing said melt into a shaped mold having the same general configuration of the final product of ultimate use; and allowing the melt to cool directly into a casting shaped to the general configuration of the final product of ultimate use.

References Cited by the Examiner

UNITED STATES PATENTS

1,990,590	2/35	Franks	75—128.5
2,903,386	9/59	Waxweiler	75—128

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