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FERRITIC CHROMIUM STEELS

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2 Claims. (Cl. 75—124)

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This invention relates to hot-workable ferritic chromium steels and articles made therefrom, and has for its principal object the provision of steels containing 20% to 30% chromium which have good impact strength in the annealed condition at room temperature.

Ferritic chromium steels exhibit good resistance to many corrosive media and, hence, have attractive possibilities for industrial use. However, steels for corrosion service are frequently needed not only to exhibit good corrosion resistance but also good toughness, and the latter needs are not filled with the conventional ferritic chromium steels because they tend to be notch sensitive at room temperature. This is especially true when the chromium content exceeds 18%. On the other hand although the austenitic chromium alloy steels have good impact properties, they are difficult to hot-work because of their great strength and low hot-ductility at elevated temperatures. Further, they contain larger quantities of alloying metals than ferritic steels and, hence, are more expensive to make. Tough ferritic chromium steel accordingly has long been a goal sought by metallurgists.

Although some expedients for providing tough ferritic chromium steels have been developed, they have not been adopted commercially to any great extent because of certain economic and inherent technical difficulties. For instance, one expedient that was advanced in U. S. Patent No. 2,120,554 requires the introduction of substantial proportions of nitrogen to the steel, together with the addition of nickel or copper or both. Difficulty encountered in the commercial production of sound high-nitrogen steels has hindered the widespread adoption of this expedient. Another attack on the problem has been directed toward the control of carbon and nitrogen. The carbon and nitrogen contents of the steels are lowered below certain values which are a function of the chromium content of the steels. For instance, the maximum tolerance for carbon plus nitrogen in 25% chromium steels is about 0.035% to achieve toughness in this way. Again, although the desired result can be obtained in the laboratory, industry is not yet ready to adopt, on a large scale, the vacuum-melting or inert-atmosphere technique required to lower the nitrogen content of the steel below the critical level.

Stainless steels are generally made in electric-arc furnaces, since they provide an economic means for refining the molten charge, and for the close control of the overall composition of the steel which is necessary to attain the properties desired. Since refining steps are possible, the arc-furnace gives the steelmaker an opportunity for utilizing scrap material and recovering economically substantial amounts of alloying materials from this scrap, as well as removing carbon. Thus, the furnace is charged with steel scrap, chromium-bearing steel scrap and a small amount of flux, and the initial charge is melted down and decarburized with an oxidizing agent such as iron ore or gaseous oxygen. The adoption of gaseous oxygen has given the steelmaker a means for attaining extremely low carbon contents since it permits the attainment of the high temperatures required to oxidize carbon preferentially to chromium. While the adoption of gaseous oxygen for oxidation permits the steelmaker to make very low-carbon steel from conventional low-carbon raw materials and steel scrap, the process will not eliminate the last traces of nitrogen from the steel. Nitrogen tends to be picked up from the atmosphere and the raw materials so that the steel contains about 0.04% to 0.07% nitrogen. Since, as previously mentioned, the carbon-plus-nitrogen content must be kept below 0.035% in 25% chromium steel for high toughness ferritic chromium steels so produced have been notch sensitive.

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In accordance with the invention, high-toughness, ferritic 20% to 30% chromium steel, having in the annealed condition an Izod impact strength averaging at least 25 ft.-lb., is produced by the introduction of aluminum, nickel and copper and by proper control of the alloying constituents and impurities to produce a substantially ferritic structure and satisfactory hot-workability. The steel of the invention exhibits enhanced toughness at levels of nitrogen and carbon, heretofore found detrimental to the toughness of ferritic 20% to 30% chromium steels. More specifically, the invention is a ferritic chromium steel containing 20% to 30% chromium, up to 0.035% maximum carbon, up to 0.08% maximum nitrogen, the sum of the carbon and nitrogen contents being greater than 0.06%; 0.25% to 1.5% aluminum, 0.5% to 3.5% nickel, up to 3% copper, the sum of the nickel and copper contents not exceeding 4%; up to 1% silicon, up to 3% manganese, the remainder iron. A small proportion, say up to 3% molybdenum, may be added to the steel to improve its corrosion resistance, if desired, without detrimentally affecting its impact strength. Conventional impurities, such as phosphorus and sulphur, may be present but should be held quite low.

The composition limits of the steel are critical.

With a higher carbon content than 0.035%, that is, in the range of carbon content that can be produced practically in the arc furnace without the use of oxygen for refinement, the toughness of the steel is lowered even though the toughening elements aluminum, nickel and copper are present. Nitrogen is also critical and should not exceed 0.08%. Within the range of 0.03% and 0.08% nitrogen, aluminum, nickel and copper effectively neutralize the embrittling tendency of nitrogen in chromium steels containing not more than 0.035% carbon. Preferably, the steel of the invention contains 0.5% to 1% aluminum, as higher percentages tend to lower toughness and decrease ductility. It is preferred that nickel constitute 0.5% to 2% of the steel. Copper may be present up to 3% in the steel, however, copper is less effective for the purpose of this invention than nickel. As above stated, when copper is present, the sum of the nickel and copper metals should not exceed 4%. When molybdenum is present, it is preferred that nickel constitute 1% to 2.5% of the steel, and when copper and nickel are both present in addition to molybdenum, it is preferred that the same of the nickel and copper content should not exceed 4%. The steel should be deoxidized, suitably with manganese and silicon, but the residual quantity of silicon in the steel should not xceed 1% as it imparts brittleness. Manganese may be present in the steel up to 3%, its action tending to supplement that of nickel and copper.

In the following table, several examples are given of steels containing about 26% chromium with varying proportions of carbon, nitrogen, aluminum, nickel, and copper together with a number of Izod impact values obtained on testing each of the steels at room temperature after they had been annealed by heating six hours at 900° C. and water-quenching.

Composition: 26% Cr; 0.35% Si; Remainder Fe and—							Izod Impact Values, Foot-pounds
Percent C	Percent N	Percent Al	Percent Ni	Percent Cu	Percent Mn	Percent Mo	
0.022	0.059	0.75	1.0	----------	0.7	----------	35, 55, 49, 47
0.025	0.059	0.75	2.0	----------	0.7	----------	30, 74, 36, 36
0.028	0.062	0.75	3.0	----------	0.7	----------	47, 93, 54, 40
0.020	0.051	0.66	3.0	----------	0.7	----------	44, 52, 59, 65
0.025	0.055	0.75	2.0	1.0	0.7	----------	44, 68, 40, 51
0.032	0.052	0.75	1.0	----------	3.0	----------	54, 49, 44, 35
0.032	0.062	0.75	2.0	1.0	3.0	----------	45, 46, 67, 76
0.025	N. D.	0.75	1.9	1.0	0.7	2.25	41, 41, 26, 42
0.025	0.074	----------	----------	----------	0.7	----------	4, 5, 5, 5
0.023	0.055	----------	2.0	----------	0.7	----------	16, 26, 33, 28
0.025	0.055	----------	1.0	----------	0.7	----------	7, 9, 10, 13

N. D.—Not determined.

For comparison, the third from last steel in the above table contains no aluminum, nickel, or copper, while the last two steels contain nickel but no aluminum. It will be evident that the addition of aluminum and nickel with or without copper raised the average impact strength from 5 ft.-lb. to well over 25 ft.-lb., and that the presence of nickel in the absence of aluminum does not produce the desired increase in toughness.

In the steel of the invention, aluminum presumably acts as a deoxidizer and a nitride former. Nickel, manganese, and copper probably increase the solubility of carbon in the steel by the formation of small quantities of austenite. Whether or not these effects are the cause of the increased impact strength of the steel of the invention, the incorporation of these elements in the proportions specified makes possible the production of tough ferritic steels containing 20% to 30% chromium by conventional melting practice using conventional raw materials.

The toughness and corrosion resistance of these ferritic steels are enhanced by employing a suitable annealing heat-treatment. In the annealing operation, the steel is held at 900° C. for a sufficiently long time to put at least a part of the carbides and nitrides into solid solution. A preferred time for this purpose is 6 hours. Following the heating for solubility and homogeneity, the steel should be cooled rapidly using air, oil, or water as the quenching medium. In the annealed condition, the steel is substantially ferritic and is formable, machineable, and suitable for manufacture into corrosion-resistant articles and numerous other products subjected to high stresses in service. The steels are not free from the tendency to embrittle when heated in the temperature range 500° C. or are they free from susceptibility to intergranular attack when heated above 900° C.

The steels of this invention may be made in Heroult-type furnaces by conventional electric arc furnace practices having general applicability to the production of stainless steels, as nitrogen does not have to be excluded from the furnace atmosphere and conventional low-carbon raw materials are employable. They can be made by induction-furnace melting practices if due regard is given to the carbon content of the raw materials, as the carbon content of the steels must not exceed 0.035%. The steels in ingot form are hot-workable at a temperature of about 2100° F., and the comparative ease of working at this temperature contributes to simplicity in achieving desired products by hot-working.

These aluminum-containing ferritic stainless steels have, by virtue of their chemical composition, good mechanical properties and corrosion resistance after a simple annealing treatment. They may be fabricated readily into products suitable for service requiring toughness and resistance to corrosion. The relative ease of melting and hot-working these steels and the fact that they can be made by conventional commercial melting practices render them economical to produce. Further, they have the advantage of requiring much smaller quantities of strategic alloying metals than the standard austenitic grades of stainless steel.

Related subject matter is described and claimed in the application of Walter Crafts, Serial No. 206,909, filed concurrently herewith and assigned to the assignee of this application.

I claim:

1. Ferritic chromium steel containing 20% to 30% chromium; up to 0.035% carbon; up to 0.08% nitrogen, the sum of carbon and nitrogen

being in excess of 0.06%; 0.25% to 3% manganese; up to 1% silicon; 0.25% to 1.5% aluminum; 0.5% to 3.5% nickel; up to 3% copper, the sum of nickel and copper not exceeding 4%: up to 3% molybdenum; the remainder iron and incidental impurities, such steel having, in the annealed condition, an average Izod impact strength of at least 25 foot pounds at room temperature.

2. Ferritic chromium steel containing 20% to 30% chromium; up to 0.03% carbon; up to 0.08% nitrogen, the sum of carbon and nitrogen being in excess of 0.06%; 0.25% to 3% manganese; up to 1% silicon; 0.5% to 1% aluminum; 0.5% to 2.5% nickel; up to 3% copper, the sum of nickel and copper not exceeding 4%; up to 3% molybdenum, the nickel content not exceeding 2% in the absence of molybdenum; the remainder iron and incidental impurities, such steel having, in

the annealed condition, an average Izod impact strength of at least 25 foot pounds at room temperature.

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