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WELDED CONSTRUCTION

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4 Claims. (Cl. 113—112)

The present invention relates to welded constructions of austenitic chromium-nickel steel alloys, and more particularly to engineering constructions made of welded parts of austenitic chromium-nickel steel alloys, possessing the property of being corrosion resistant, and being insensible to attack of most acids or salt solutions, even at elevated temperatures.

Heretofore, it was well known that steel could be made stainless under certain conditions by the addition of nickel and chromium in certain proportions. Thus, in my earlier United States Patents Nos. 1,316,817 and 1,339,378 I have disclosed steels containing nickel and chromium which possess resistance against corrosion. It was found advantageous for many purposes, including ease of working, shaping and fabricating these corrosion-resisting steels into articles of manufacture, to have them substantially in an austenitic condition, that is, with the iron possessing the gamma instead of the alpha structure. Such steels of austenitic structure have a particularly good ductility. The austenitic condition was obtained by having the nickel and chromium present in the steel in such an amount as to insure an austenitic structure when the steel had been properly heat treated, that is, quenched (rapidly cooled) from a temperature of about 1000° C. to 1250° C.

Monypenny in his textbook entitled "Stainless Iron and Steel" (1926), discloses, on page 127, the early Strauss and Maurer diagram showing the effect of the nickel content on the production of austenite in high chromium steels. This diagram was based on an article entitled "Die Hochlegierten Chromnickelstähle als Nichtrostende Stähle" (Kruppsche Monatshefte, August, 1920).

Subsequently I published an article entitled "Non-rusting chromium-nickel steels" in 1924 (A. S. T. M., vol. 24, part II, Technical Papers, pp. 208–216.) On page 209 of my article I illustrate a diagram of quaternary chromium-nickel steels, which depicts quite clearly the necessity of correlating nickel and chromium in order to produce austenite (with proper heat treatment). in the stainless chromium-nickel steels.

Bain and Griffiths in 1927, in their publication entitled "An Introduction to the Iron-Chromium Nickel Alloys" (Trans. A. I. M. E., vol. LXXV, pp. 166–213 (1927), gave a comprehensive and systematic discussion of the so-called stainless chromium-nickel steel alloys. In this publication, Bain and Griffiths give constitutional diagrams of the chromium-nickel-iron system at various temperatures. By this publication, the art was made aware of the fact that the nickel and chromium had to be present in certain amounts, under various thermal conditions, in order to produce austenite or an austenitic structure.

In working certain of the austenitic stainless steels, for example austenitic steels containing 18% chromium and 8% nickel, particularly from elevated temperatures, as in forging, they became difficult to work, and didn't possess their best corrosion resistance. In my United States Patent No. 1,404,908, I disclosed a method of treating such alloys for the purpose of restoring the workability and the austenitic state by a high-temperature heat-treatment, followed by a quench or rapid cooling.

It was first thought that the austenitic chromium-nickel stainless steels lent themselves to welding. Thus Monypenny, supra, on page 248 states that:

> The austenitic alloys may be soldered or brazed without difficulty. They may also be welded with the electric arc or the oxy-acetylene blowpipe more easily than ordinary stainless material. As they do not harden on cooling rapidly from high temperatures, they do not suffer from the disabilities of ordinary stainless steel in this respect. They may also be welded by the above processes to ordinary stainless steel, giving very satisfactory joints.

Welded structures built up of austenitic stainless steels appeared to be satisfactory after welding, but when such welded structures were exposed in service to corrosive conditions, even to liquids regarded as being only mildly corrosive, defects developed. The most serious defect was the failure of the steel in a region adjacent to the weld. In discussing the welding of stainless steel, Carter and Miller, in their article entitled "Oxy-acetylene welding in chemical plant construction" (Industrial and Engineering Chemistry, vol. 19, No. 6, June (1927), on page 696 state that:

> The corrosion-resisting alloys are often troublesome, not on account of their welding, but because of a changed condition of the metal adjacent to the weld. This may be called a welding problem, but is just as much a problem for anyone who is flanging such alloys or is in any way heating the metal to temperatures above the critical range. Certain alloys will, undoubtedly, always give trouble under the effects of high temperatures because of grain growth, which cannot be broken up by annealing. It therefore behooves the purchaser and fabricator to learn everything

possible about the dependability of a fabricated structure rather than judge the suitability of a material entirely by its corrosion resistance.

In "Engineering" (April 20, 1928, London), a statement is made, on page 478, that:

> . . . it has been found that slight selective corrosion had occurred in austenitic steels which had been exposed to a welding heat. Exhaustive research had shown that when the material was subjected to prolonged heating at temperatures between 800 deg. and 850 deg. C., it was more liable to corrode than was austenitic steel in the fully softened condition. Here, again, correct heat treatment, involving a reheating of the material to the usual softening temperature of from 1,000 deg. to 1,200 deg. C., completely restored the corrosion-resisting properties of welded austenitic alloys.

The restoration of the austenitic condition in fabricated constructions or structures subsequent to welding, by heating the entire structure to elevated temperatures within the range of about 1000 to 1250° C. and then rapidly cooling the entire structure was the only known solution of the problem of preventing this "selective" corrosion in the regions adjacent to the welds, in fabricated structures of austenitic chromium-nickel stainless steel. While small articles of manufacture could be heated and quenched with some measure of success, it was impracticable if not impossible to apply this heat treatment to large receptacles, containers, and the like, for a number of reasons, including the difficulty and expense of constructing furnaces in which such large structures could be heated, the difficulty of quenching large structures uniformly, even if furnaces could be constructed in which to heat them, the difficulty of designing and fabricating large structures capable of withstanding the stresses and strains incident to this heat treatment without distortion or even collapsing, in the weakened condition, at the elevated temperatures to which the structure had to be heated in order to restore its corrosion resistance. The expense of heat treating structures fabricated of pieces of austenitic stainless chromium-nickel steel, by welding, made the final cost of such structures prohibitively high for most applications where the steel otherwise would have found commercial application.

As is well known, large receptacles, containers, equipment, and the like, were fabricated by welding together sheets or plates, tubes, shapes, etc., of austenitic chromium-nickel stainless steels. Butt and lap joints have been used for joining the edges of sheets and plates, as those skilled in the art know. Representative examples of receptacles, containers, equipment and the like are tanks, vats, evaporators, heat exchangers, pasteurizers, mixers, dryers, kettles and digesters used in the industries. These welded structures were satisfactory, when used for the storage of non-corrosive matter, and were also satisfactory even when used for the storing or otherwise containing corrosives, provided such structures had been properly heat treated, after welding, as heretofore indicated. However, when used in connection with corrosives, without having first been subjected to such heat treatment, it was merely a matter of time, and a comparatively short time at that, before failure of the material resulted in the zones which lie in the proximity of the weld.

This failure was not due to surface corrosion (to which chromium nickel steel is resistant), but to what is now known as intergranular corrosion—that is, a corrosion taking place at the boundaries of the metal grains mainly within the interior of the steel section.

Summarizing the situation, those skilled in the art knew that corrosion resistant austenitic-chromium-nickel steel alloys hitherto used in the production of nitric acid and of other chemical agents suffered from the drawback of being no longer resistant, e. g., to the attack of acids or salt solutions, if they have experienced, e. g., in welding together individual parts of a construction, a heating to about 600 to 900 degrees C., which comes up to a tempering treatment.

The art was confronted with the vexatious problem of providing a welded structure composed of an austenitic chromium-nickel stainless steel which would not corrode adjacent to the weld when the welded structure was exposed, without further heat treatment, to corrosive influences. None of the proposals or attempts, as far as I am aware, provided a solution which was thoroughly satisfactory and successful, especially when carried into practice on a practical and industrial scale for the production of commercial products, articles, structures or constructions.

The invention has for its object to provide austenitic chromium-nickel steel alloys, e. g. alloys containing 18 to 25 percent of chromium and 7 to 12 percent of nickel, that are free from the drawback of being no longer resistant to attack when welded and nevertheless show all the advantages afforded by the known corrosion resistant austenitic chromium-nickel steel alloys. This object is obtained according to the invention by determining the carbon at less than 0.07% to make sure that the welded steel does not suffer from intergranular corrosion.

The reason for the surprising feature of the indicated steel alloy containing less than 0.07% of carbon and possessing the property, very important in engineering, of being insensible, e. g. to the attack of acids or salt solutions, resides, as found by my investigations in the fact that no detrimental carbides are formed even if during welding the steel is heated to between 600 and 900° C., adjacent to the welding seam. Hitherto the corrosion resistant austenitic chromium-nickel steel alloys were usually made with 0.1 to 0.4 percent of carbon. In these latter chromium-nickel steel alloys when heated to about 600 to 900 degrees C., as occurring in the neighborhood of welding seams, the carbon is separated from the base mass and after having formed a compound with the chromium, deposits as chromium carbide at the grain boundaries of the crystal grain. This chromium carbide separates in a critically heated zone in proximity to the weld and causes decomposition of the alloy at the grain boundaries when attacked by acids or salt solutions (i. e. corrosive media). The critically heated zone is that band or strip of the alloy in proximity to the weld which has been heated within the range of about 600° C. to about 900° C. by the heat flowing from the weld during the welding as pointed out hereinabove.

It is to be observed that the present invention provides a welded construction comprising a plurality of individual parts, a weld between said parts and joining them together, and a critically heated zone occurring in proximity, or adjacent, to said weld and being in a condition resulting from heating to temperatures of about 600° C. to about 900° C. due to welding, said welded construction being composed of substantially austenitic chromium-nickel steel alloy, with less than 0.07% carbon, said alloy being free of detrimental chromium carbides.

It is likewise to be observed that the present invention provides a welded construction comprising a plurality of individual parts, a weld between said parts and joining them together, and a critically heated zone occurring in proximity, or adjacent, to said weld, and being in a condition resulting from heating to temperatures within the range of about 600° C. to about 900° C. due to welding, said welded construction being composed of a substantially austenitic chromium-nickel steel alloy containing, by way of example, about 18 to 25 percent of chromium and 7 to 12 percent of nickel, the percentage of carbon of which is so determined that no detrimental segregation thereof in the grain boundaries occurs even when the alloy is subjected to a heating that is equivalent to a tempering treatment, and said welded construction being particularly composed of an austenitic chromium-nickel steel alloy containing less than 0.07 percent of carbon.

Moreover, the present invention provides a welded construction comprising a plurality of individual parts, a weld between said parts and joining them together, and a critically heated zone occurring adjacent to said weld and being in a condition resulting from heating to temperatures within the range of about 600° C. to about 900° C. due to welding, said construction being composed of a substantially austenitic chromium-nickel steel alloy containing, by way of example, about 18% to about 25% of chromium, about 7% to about 12% of nickel, and less than 0.07% of carbon and possessing a structure constituted substantially of austenite free from detrimental deposits of carbides at the grain boundaries of the crystal grains including those in said critically heated zone and said construction including said critically heated zone being resistant to decomposition and to attack including attack by acids and salt solutions.

Without deviating from the substance of the invention, it would be possible to add to the indicated steel alloys still ingredients that improve their properties, e. g. molybdenum, copper, etc., and to leave remaining in the alloys other elements, including impurities, usually found in stainless steels. Also, two edges of a single sheet of material may be joined by welding, and when this is done the portions of the sheet adjoining each edge constitute the individual parts referred to in my claims. When I speak, in my claims, of "austenite free from deposits of carbide" it would be within the spirit and scope of my invention to have such austenite substantially free from deposited carbide, provided such deposit as may be present does not detrimentally affect the stability of the alloy. When I speak in my claims of resistance to acids and salt solutions, I do not intend to imply that the structures are resistant to any solutions of this type to which, as was well known to those familiar with the art, austenitic chromium-nickel steels are not resistant.

The present application is a divisional application of my co-pending application Serial No. 330,429, filed January 4, 1929, and entitled "Austenite chromium-nickel steel alloys."

When I speak in my claims of a "non-heat treated welded construction," I mean a welded construction which has not been given, after welding, the stabilizing treatment (restoration to austenitic condition), hereinabove referred to, of first heating to about 1000° C. or higher, and then rapidly cooling.

It is obvious, from what has been hereinabove stated, that my invention is based upon the discovery that, if the carbon in corrosion resistant austenitic chromium nickel steel alloys is maintained at extremely low percentages, intergranular corrosion will not result from exposure to the deleterious range of temperature developed in some portion of the welded article by the high temperature accompanying the welding operation, followed by exposure to a corrosive, and that this makes it unnecessary to restore the former condition of the material, after welding, by heating the entire structure to an elevated temperature (1000° to 1250° C.) and then rapidly cooling the entire structure, a procedure which heretofore constituted the only known solution of the problem of preventing intergranular corrosion in the regions adjacent to the weld. As has already been stated, it is impracticable, if not impossible, to apply this subsequent heat treatment to large articles, such as large receptacles. It is, of course, obvious, that such treatment cannot be applied to articles which are not amenable to a subsequent high heat treatment because of danger of distortion or because of location.

My invention is therefore applicable to such structures as are designed for exposure to liquids, such as acid or salt solutions, which are capable of inducing local electrolytic action between dissimilar metals and thus act as electrolytes and induce corrosion (Speller, Corrosion—Causes & Prevention—2d ed., p. 9 et seq.). Such structures may accordingly be properly termed "electrolyte contactors."

What I claim and desire to secure by Letters Patent is:

1. A non-heat treated welded construction comprising a plurality of individual parts, a weld between said parts and joining them together, and a critically heated zone occurring adjacent to said weld, said individual parts being composed of an alloy steel containing about 18% to about 25% of chromium, about 7% to about 12% of nickel, and less than 0.07% of carbon and possessing a structure constituted substantially of austenite free from deposits of carbides at the grain boundaries of the crystal grains, including those in the critically heated zone, and said construction, including said heated zone, being resistant to decomposition and to attack, by acids and salt solutions.

2. An electrolyte contactor constituted of a plurality of parts united by a fusion weld, each of such parts being composed of an austenitic chromium nickel steel alloy containing from about 18% to about 25% of chromium, from about 7% to about 12% of nickel, the balance, with the exception of carbon, being substantially all iron, said contactor being resistant to intergranular corrosion, although not having been subjected, after welding, to a heat treatment followed by rapid cooling, the alloy being characterized by the fact that its carbon content is less than .07%.

3. An electrolyte contactor of such size as not to be amenalbe to a uniform heat treatment at a temperature of 1000° C. or above and constituted of a plurality of parts united by a fusion weld, each of such parts being composed of an austenitic chromium nickel steel alloy containing from about 18% to about 25% of chromium, from about 7% to about 12% of nickel, the balance,

with the exception of carbon, being substantially all iron, said contactor being resistant to intergranular corrosion, although not having been subjected, after welding, to a heat treatment followed by rapid cooling, the alloy being characterized by the fact that its carbon content is less than .07%.

4. The improvement in the art of preparing welded steel alloy articles which are resistant to both surface and intergranular corrosion, which consists essentially in first preparing an austenitic steel alloy containing from about 18% to about 25% of chromium, from about 7% to about 12% of nickel, and less than .07% of carbon, the balance being substantially all iron, and thereafter uniting a plurality of portions of such alloy by welding, thereby obtaining an article which may be brought into contact with a corrosive liquid without having first been subjected to a heat treatment of the order of 1000° C. or higher.

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