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PROCESS OF TREATING AUSTENITIC CHROME-NICKEL STEEL ALLOYS

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The object of my invention is the manufacture of articles of chrome-nickel austenitic steel which will be resistant to intercrystalline attack, commonly indicated by the Strauss test, after they have been heated in normal use to a temperature within about a range of 1000 to 1500 or 1600° F. The process finds its most useful application in the treatment of the so-called "18—8" chrome-nickel austenitic steel, within which may be included alloy steel having percentages of chromium and nickel somewhat greater or smaller than the percentages specified. The process is also applicable to the manufacture of chromium-nickel steel whose chromium and nickel contents vary rather widely from the precentages specified. The problem of manufacturing "18—8" chrome-nickel steel that will be resistant to corrosive agents within the range of temperature specified is less difficult of solution if the carbon content be relatively low, say of the order of 0.06%, but the added expense of producing such alloy steel so low in carbon is in most cases a serious element of cost. My improved process has its chief commercial value when applied to chrome-nickel alloys having a considerably higher carbon content, say of the order of .25 or .30%, although it is also equally applicable to such alloys that have a very low carbon content.

The cause of the lack of adequate resistance to corrosive agents at high temperatures exhibited by chrome-nickel austenitic steel when manufactured in accordance with conventional methods has been explained in prior patents and publications and need not be herein discussed. It will suffice to explain the procedure embodying my invention and the variations therefrom which are advisable or necessary with variations in the carbon content. The technical effects which it is believed my improved process achieves will also be explained, although it will be understood that such explanation is based upon microscopic examination and may not be as accurate and complete as more exhaustive investigations may disclose. That the process does render the steel alloy resistant to corrosive agents without development of brittleness or loss of durability when heated to within the specified temperature range has been, however, conclusively demonstrated by the practical use of the process.

In the first step of my process, the alloy is heated to a temperature above that at which carbon is in substantially complete solution in the metal. That temperature increases as the carbon content of the alloy increases. For carbon as low as .06% in a steel alloy of 18% chromium, 8% nickel, this temperature is about 1650° F.; for a carbon content of .25% this temperature is between 1900 and 1950° F. The temperature to which the alloy must be heated in the first step of my process is therefore variable, but ordinarily it will suffice to heat the billet to a normal hot rolling temperature, usually 1900° to 2100° F.

Immediately after heating to the temperature specified, or before the temperature has dropped to a temperature at which a substantial portion of the carbon goes out of solution, the metal is subjected to normal hot working, such as forging, pressing or rolling. The progress of reduction by hot working is, however, so timed that the piece, when it arrives at the point of final reduction to finished size, is at a temperature at which the larger part of the carbon is out of solution. Thus, dependent usually upon the percentage of carbon in the alloy, the metal is heated to a temperature the minimum of which could vary from about 1650° to 1950° F. and the hot working, starting at about that temperature, is finished at a temperature which may vary within wide limits, say from about 1800° down to about 1050° F., but which must be substantially below the temperature of the original heating. Thus, if an "18—8" chrome-nickel steel alloy contains .25% carbon, the hot working operation may be completed at below 1650° F., at which temperature about .06% carbon will be in solution; but it is preferable to continue the hot working operation to a decidedly lower temperature when still less carbon will be in solution. At a temperature below 1500° F. only about .025% carbon would remain in solution. If said alloy contains only .06% carbon, the hot working operation, in order to effect an improvement, must be completed at below 1500° F., at which temperature, as just stated, about .025% carbon will be in solution. Working to the lower temperature has the further advantage that the precipitated carbides will be more thoroughly broken up by a working continued after their precipitation. In all cases, however, it is necessary that the temperature at the completion of working shall be at or below that at which the larger proportion of the carbon is out of solution. In no case should the working continue after the temperature approaches 1000° F.

The effect of rolling or other working while carbon is being precipitated from solution is to break up the continuity of the envelope of carbide which forms normally about the individual crystals of the metal.

After finishing the rolling or other working, the

bar is cooled. Preferably, but not necessarily, it is allowed to cool, in the air, to atmospheric temperature.

In this "as rolled" or "as worked" condition the metal does not possess its full corrosion resistance but is disintegrated by attack of acids at grain boundaries after being subjected to a temperature within the range 1000 to 1500° F.

In order to render the alloy immune to such attack, it is reheated to a temperature below that at which any considerable proportion of carbides is dissolved, held at that temperature for a material length of time, say from two hours to 48 hours or somewhat longer, but preferably about 48 hours and then cooled, the rate of cooling being immaterial. The maximum temperature of reheating, in the case of "18—8" chrome-nickel steel, should not be above that at which 0.25% of carbon is in solution and therefore should not reach 1500° F.

In treating chrome-nickel steel containing a high percentage of chromium, the temperature of reheating may be considerably above 1500° F., since a high percentage of chromium permits a greater proportion of carbides out of solution without depleting the adjacent metal to a point where it becomes susceptible to corrosion. The permissive temperature of reheating may also vary with different carbon contents and may be higher with higher carbon chrome-nickel alloy steel than with lower carbon chrome-nickel alloy steel, because it takes a higher temperature or longer time to secure the redistribution of chromium to the depleted areas when a larger amount of carbide has lowered to a greater degree the chromium in the adjacent metal. Preferably the temperature of reheating of an alloy containing .25% carbon should not be above about 1400° F. while with lower percentages of carbon down to .06% the temperature of reheating should, preferably, not be above the range of 1200–1300° F. The temperature of reheating may also vary with the temperature at which the hot working was completed. Thus, if the hot working were completed at a temperature of 1400° F., the reheating temperature may be as low as 1100° F. or even lower. If the temperature at which the hot working was finished were comparatively high, say just below 1650° F., the reheating temperature should not be below about 1300° F. If this reheating temperature be as high as 1600° F., the material will still be immunized but comparatively soft, which is desirable for some purposes. The lower temperature will give as good or better immunization with higher physical properties.

The following table gives illustrative reheating temperatures which in 48 hours will produce full resistance to acid attack in metals, of different carbon contents, the rolling of which has been completed at the temperatures given in the first horizontal column of figures:

Percent carbon	1450° F.	1565° F.	1680° F.	1795° F.
0.06	1200	1200		
0.18	1300	1300	1300	1400
0.23	1300	1300	1300	1400

The reheating has three effects, namely: (1) the more complete spheroidization of the carbides; (2) the more complete liberation from solution of carbon; and (3) diffusion of chromium into portions around the carbides from which chromium has been extracted in the formation of the carbides.

Chromium-nickel austenitic steel, when processed by the above method of rolling and reheating, is immune to intercrystalline attack by the Strauss reagent following a heating in the range of 1000 to 1600° F.

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

1. The herein described method of treating nickel-chromium-carbon steel alloys to render them resistant to corrosion after subjection to a temperature within a range of 1000 to 1600° F., which comprises heating the alloy to such temperature above 1650° F. that the carbon is in substantially complete solid solution in the alloy, then subjecting the alloy to a hot working operation through a temperature zone ranging from the temperature specified at the beginning of the working to such temperature below a maximum of 1650° F., at which the larger percentage of carbon will be out of solution, then cooling the alloy, then reheating the alloy to a temperature in excess of 1000° F. but below 1800° F. and substantially below the temperature of the first heating, holding the alloy at that temperature for a substantial period of time, and then cooling to atmospheric temperature.

2. The herein described method of treating nickel-chromium-carbon steel alloys to render them resistant to corrosion after subjection to a temperature within a range of 1000 to 1600° F., which comprises heating the alloy to such temperature above 1650° F. that the carbon is in substantially complete solid solution in the alloy, then subjecting the alloy to a hot working operation through a temperature zone ranging from the temperature specified at the beginning of the working to a temperature between 1050° and 1500° F. at which the larger percentage of carbon will be out of solution, then cooling the alloy, then reheating to a temperature in excess of 1000° F. but below 1600° F., holding the alloy at that temperature for a substantial period of time, and then cooling to atmospheric temperature.

3. The herein described method of treating nickel-chromium-carbon steel alloys to render them resistant to corrosion after subjection to a temperature within a range of 1000 to 1600° F., which comprises heating the alloy to such temperature above 1650° F. that the carbon is in substantially complete solid solution in the alloy, then subjecting the alloy to a hot working operation through a temperature zone ranging from the temperature specified at the beginning of the working to a temperature between 1050° F. and 1500° F. at which the larger percentage of carbon will be out of solution, then cooling the alloy, then reheating to a temperature in excess of 1000° F. but below 1500° F., holding the alloy at that temperature for a substantial period of time, and then cooling to atmospheric temperature.

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