Patented Sept. 11, 1945

2,384,567

UNITED STATES PATENT OFFICE

2,384,567

ALLOY STEEL METHOD AND PRODUCTS

Henry S. Schaufus, Baltimore, Md., assignor to Rustless Iron and Steel Corporation, a corporation of Delaware

No Drawing. Application December 13, 1940, Serial No. 370,074

7 Claims. (Cl. 148—31)

My invention relates to products fashioned of a high chromium alloy steel, especially a free-machining steel as disclosed in my co-pending application Serial No. 370,072 filed of even date herewith and entitled Alloy steel and articles and to an art or method of producing the same.

Among the objects of my invention is the provision of a simple, direct and economical art for uniformly obtaining high chromium alloy steel products, such as bars, rods, wire, plate, sheet, tubes, forgings, drop-forgings and the like (especially to such products having good machining characteristics by virtue of substantial sulphur content), of high impact strength in spite of temperature variations in the working operations and in the various finishing temperatures encountered in actual practical use, and to the semi-converted products themselves as produced in accordance with my method.

Other objects of my invention in part will be obvious and in part pointed out hereinafter.

The invention accordingly consists in the composition of ingredients, combination of elements and mixture of materials and in the several operational steps and the relation of each of the same to one or more of the others as described herein, the scope of the application of which is indicated in the claims.

A better appreciation of my invention perhaps best may be gained through a general preliminary consideration of certain of the heretofore known and used high chromium alloy steels, commonly referred to as stainless steel. One of the most common types is the 12% to 14% chromium grade. The steel is readily workable into bars, rods, wire, plate, sheet, strip and tubes through conventional hot or hot and cold methods. It may be heat-treated to give a wide range of hardness, strength and impact resistance. Moreover, the products readily may be fashioned through riveting, welding or soldering methods into a host of articles of ultimate use. This steel is reasonably strong and tough and possesses an excellent impact strength. Even the free-machining grades of this steel are high in impact strength. The 12% to 14% chromium grade, however, is severely limited in its corrosion resisting properties; it is recommended only where the most mild form of corrosive agents are encountered.

Where rather severe corrosive conditions are to be encountered the austenitic grades of chromium-nickel stainless steel, that is, stainless steel having about 18% chromium and 8% nickel, commonly are used. This steel likewise may be worked in a conventional way to give the usual converted forms. Also it may be fabricated into a host of articles and products of ultimate use. The steel is strong, tough, ductile and of good impact strength, both in the common grade and in the free-machining grade where the ingredient sulphur is included in substantial quantity. The steel, however, is not hardenable by heat treatment and moreover it is quite expensive largely because of its high nickel content.

While it might be expected that a reasonably inexpensive stainless steel of desired physical and corrosion resisting properties could be had in some higher chromium grade, for example, a 17% chromium grade, I find that this is by no means the case, especially where the steel contains a substantial amount of sulphur to give it free-machining qualities. The 17% chromium grade, particularly of the free-machining type, although possessed of good working properties and good corrosion resisting characteristics, seriously suffers in impact strength. For this reason it is not recommended in applications where shock, vibration, or other active stresses are commonly met with in use. This is particularly true of the sulphur-bearing steel which is so low in impact strength as to be virtually worthless for engineering applications.

Now in my co-pending application for patent identified above, I have described and claimed a stainless steel having good impact strength in combination with good corrosion resistance, and good machineability, which at the same time is hardenable by heat treatment and comparatively inexpensive. Also in my co-pending application, Serial No. 370,073, filed of even date herewith and entitled Method of working alloy steel and products thereof, I have described and claimed a method by which best results are had in a steel of that general character. I find, however, that it is somewhat difficult to exercise proper control of temperature in converting billets and blooms into bars, rods and wire or plate and sheet, as the case may be. Where the critical temperatures of my method referred to are substantially departed from, I find that the impact strength greatly suffers.

One of the outstanding objects of my present invention accordingly is the provision of an economical method for uniformly and consistently obtaining high chromium stainless steel converted products especially of the free-machining grade, of high impact strength, in spite of temperature variations in the working operations

and in spite of a variance in the finishing temperatures.

Turning now to the practice of my invention, stainless steel containing 14.5% to 18.0% chromium, .5% to 2.0% nickel and .06% to .30% nitrogen, with a maximum of .20% carbon and the remainder principally iron (together with a sulphur content of .20% to .50% for the free-machining grade), is produced according to any one of several well-known melting processes such, for example, as those generally described in the United States Letters Patent 1,925,182, issued to Alexander L. Feild on September 5, 1933, and entitled Process for the manufacture of rustless iron, or United States Letters Patent 2,056,162, issued to William B. Arness on October 6, 1936, and entitled Production of rustless iron. The nitrogen addition is conveniently made as described in the co-pending application of William B. Arness, Serial No. 113,258, filed November 28, 1936, and entitled Production of rustless iron. The sulphur addition conveniently is made in the conventional manner through the addition of lump sulphur to the ladle in tapping the heat of metal.

The steel is worked from ingots to billets or blooms and thence to bars, rods and wire in the one case or plate and sheet in the other through conventional hot-working methods. Similarly, where desired, certain of the converted or semi-converted forms may be forged or drop-forged in the production of semi-finished articles. The products are reheated to a temperature of 1000° F. to 1450° F. and air-cooled.

These various converted products are made into a wide variety of articles of ultimate use. Converted articles of the free-machining grade are fashioned into various machine parts such as gears, worms, spindles, shafts, sleeves, bushings, rings, and discs, as well as threaded bolts, pins, studs, nuts, valve parts and the like wherein cutting, drilling, tapping, threading or other machine operations are required.

In accordance with my invention I find that the converted products as well as the products of ultimate use fashioned thereof are strong and tough. Those of the higher carbon grade, .12% to .20% carbon, lend themselves to considerable hardening by heat-treatment. In all grades, this including the non-hardening grade wherein the chromium content is preserved at 14.5% to 16.5% and the carbon content is .12% or less, the corrosion resistance is good and the impact resistance likewise is good. This combination of properties is rather surprising, particularly in the free-machining grade. The articles fashioned of my steel are admirably adapted to withstand the bending, torsion, impact and like stresses encountered in use.

While it is difficult to explain fully the reason for the surprising combination of good impact strength and good corrosion resistance in products converted according to my invention, in spite of variations in the working temperatures employed, this nevertheless is an accomplished fact. Especially is this so in connection with the free-machining grade of steel where the combination of good impact strength, good machineability and good corrosion resistance is realized in converted products even where the temperatures of conversion widely vary. For some reason unknown to me the presence of nitrogen directly contributes to the realization of this result.

As illustrative of one of the features of my invention, a comparison is given between converted products of a low nitrogen steel and a high nitrogen steel which in other respects are of like analyses. The compositions of the two steels are given in Table I, as follows:

Table I

Ingredients	Low nitrogen	High nitrogen
Chromium	16.25	16.05
Sulphur	.31	.23
Nickel	.76	.73
Nitrogen	.02	.06
Molybdenum	.41	.37
Manganese	.63	.67
Silicon	.39	.46
Carbon	.07	.09
Iron	Remainder	Remainder

Two sample ingots of each analysis were rolled down, one at a higher working temperature than the other. Although all four ingots rolled well, it is significant that in the low nitrogen samples there is a wide difference in the impact strengths realized. In the case of the high nitrogen samples, however, it is noted that the impact strengths are virtually the same in spite of the temperature differences in the two rolling operations. A comparison for the four samples is given in Table II below:

Table II

Sample	Rolling temperatures		Structure	Grain	Impact Izod, foot lbs. (annealed)
	Start	Finish			
	°F.	°F.			
Low nitrogen	2,210	1,700	60% ferrite remainder decomposed martensite.	Slightly elongated	6-12
Low nitrogen	1,925	1,000	60% ferrite remainder decomposed martensite.	Greatly elongated	41-46
High nitrogen	2,210	1,700	30% ferrite remainder decomposed martensite.	Slightly elongated	28-35
High nitrogen	1,925	1,000	30% ferrite remainder decomposed martensite.	Slightly elongated	31-38

From the comparison given above it will be observed not only that the presence of nitrogen assures uniform high impact strength in spite of vagaries in the working temperatures, but also that the presence of nitrogen substantially reduces the directional effects in the products. This is particularly important in the converted products which subsequently are to be made into various machine parts where it is readily understood that the various bending, torsion, impact and other stresses encountered in actual practical use may be applied in an infinite number of directions.

While as more particularly indicated above my novel method of lending good impact strength to high chromium stainless steel converted products is illustrated in connection with a high chromium

low nickel steel, certain further advantages are had by introducing a manganese content in excess of that normally present, the manganese content ranging then up to 1.5% and desirably being between .5% and 1.5%.

The ingredient silicon, which, like manganese is commonly present in stainless steel, preferably should be maintained at a low value, that is, no more than about .35%, although where the nickel is on the high side and the chromium is on the low side the silicon proportionately may be higher, up to about .60%.

Certain further advantages are had in the converted products produced in accordance with my invention where the ingredient molybdenum in the amount of .2% to 2.0% is included in their composition. This ingredient preferably is preserved in amounts of .2% to 1.0% in the non-hardening grades of my steel. I find that molybdenum lends a certain denseness to the metal and imparts peculiar wear-resisting qualities to the articles of use into which the converted products are fashioned, as more particularly indicated in my co-pending application referred to above and entitled Alloy steel and articles.

Thus it will be seen that there has been provided in my invention an art of uniformly obtaining high chromium alloy steel products in spite of variations in the working temperatures encountered in actual practical operations. It will be seen that the process of my invention is simple, direct and economical. Also, it will be seen that in accordance with my invention uniform high impact strength is had even in the free-machining grades of stainless steel converted products. The converted products possess a surprising combination of corrosion resistance and high impact strength which are substantially free of directional effects and which lend themselves to fabrication into a host of articles of ultimate use.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiments hereinbefore set forth, it will be understood that all matter described herein is to be interpreted as merely illustrative of my invention and not as a limitation.

I claim as my invention:

1. In the production of hot-worked alloy steel semi-converted products, of good machining characteristics, comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, with a maximum of .20% carbon and the remainder substantially all iron, the art which includes assuring improved impact strength in such products in spite of irregularities in the hot-working operations, by including in the composition of the alloy steel the ingredient nitrogen in the amount of .06% to .30%, and air-cooling the steel from a temperature of 1000° F. to 1450° F.

2. In the production of hot-worked alloy steel semi-converted products, of good machining characteristics, comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, with a maximum of .20% carbon and the remainder substantially all iron, the art which includes assuring high impact strength in such products in spite of irregularities in the hot-working operations, by including in the composition of the alloy steel the ingredients nickel, in the amount of .5% to 2.0% and nitrogen in the amount of .06% to .30%.

3. In manufactures of the class described, semi-converted hot-worked alloy steel products of good machining qualities and of uniformly improved impact strength, such products comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, .06% to .30% nitrogen, a maximum of .20% carbon and the balance substantially iron.

4. In manufactures of the class described, semi-converted hot-worked alloy steel products of good machining qualities and of uniformly improved impact strength, such products comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, .06% to .30% nitrogen, .2% to 2.0% molybdenum, a maximum of .20% carbon and the balance substantially all iron.

5. In manufactures of the class described, hot-worked alloy steel bars, rods and wire of good machining properties and high impact strength, comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, .06% to .30% nitrogen, a maximum of .20% carbon and the balance substantially all iron.

6. In manufactures of the class described, hot-worked alloy steel plate and sheet of good machining characteristics and high impact strength such alloy steel plate and sheet comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, .06% to .30% nitrogen, with a maximum of .20% carbon and the remainder substantially all of iron.

7. In manufactures of the class described, alloy steel drop-forgings of good machining characteristics and high impact strength, comprising 14.5% to 18.0% chromium, .20% to .50% sulphur, .5% to 2.0% nickel, .06% to .30% nitrogen, with a maximum of .20% carbon and the remainder substantially all of iron.

HENRY S. SCHAUFUS.