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STAINLESS STEEL PROCESS

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The present invention relates to high-chromium stainless steel alloys of high-carbon contents, and particularly to an art of heat-treating and working the same.

One of the objects of my invention is the provision of a simple, direct and practical process for improving the cold-working properties of high-chromium stainless steel alloys of high-carbon contents, which enables the employment of conventional equipment at maximum efficiency and with minimum expense.

Another object of my invention is the cold-reduction of stainless steel bars, rods and wire, of the class indicated, in an economical manner with a minimum number of operational steps and with a minimum of waste and breakage of metal stock.

Another object of my invention is the production of cold-worked bars, rods and wire of improved metal grain structure which are strong, sound and durable and which possess great hardness and improved corrosion resistance.

Other objects, in part, will be obvious and in part pointed out hereinafter.

The invention accordingly consists in the several operational steps, and in the relation of each of the same to one or more of the others as described herein, the useful application of which is indicated in the claims.

To promote a clearer understanding of my invention, it is to be noted at this point that the hardenable hypereutectoid, high-chromium stainless steel alloys comprising 16% to 22% chromium, 0.75% to 1.5% carbon, and the balance substantially iron, except for special purposes, small additions of molybdenum and the like, are metals of great strength, toughness and hardness, possessing high resistance to corrosion and abrasion. Because of excellent serviceability, these alloys enjoy a wide range of utility, being employed in such applications as the production of ball bearings, cutlery, valves, valve seats, dental instruments, superheated steam parts, milk bottling equipment, oil pumps, spraying machines, laundry equipment, chemical equipment, and the like.

Alloys of the class described, however, have, as the result of hot-working, objectionable brittleness, which condition persists even where the metal is annealed after hot-working. Before cold-drawing, a high-carbon, high-chromium stainless steel into rods or wire, for example, it is conventional practice to hot-roll the metal

through an initial range of reduction. Thereafter, the metal is exposed alternately to annealing, pickling and cold-drawing operations until the metal is drawn to rods or wire of final size.

5 Much difficulty is encountered in the form of breakage during the cold-drawing steps, because of metal brittleness incurred by hot-rolling. Cold-drawing of high-carbon, high-chromium stainless steel alloys in accordance with prior
10 practice, therefore, is tedious, time-consuming, and consequently, uneconomical. Moreover, fault often is found with finished metal products because they contain flaws, have irregular grain structure and lack strength, toughness and durability.

15 Although I do not care to be bound by an explanation, it appears that part of the carbon in hypereutectoid stainless steels is in solid solution with iron and chromium, while another part is in the metal carbide form. When an alloy steel of the class described is hot-rolled, carbide particles segregate in the metal to disrupt uniformity of the metal grain structure. Upon cooling from
20 the hot-rolling temperature, the metal is found to be objectionably brittle. In accordance with previous practice, annealing of the hot-rolled metal at 1500° F. to 1600° F. serves to soften the metal and to relieve stresses incurred by hot-rolling. In spite of the annealing operation, difficulty is encountered in cold-working the metal
30 into rods and wire, as by drawing, because of its excessive brittleness and lack of uniform grain structure. After cold-working the metal, grain structure is not uniform, apparently because of the presence of carbide segregation. The resultant rod or wire products are not entirely uniform in strength, toughness, hardness, corrosion resistance and abrasion resistance.

40 An object of my invention, accordingly, is the provision of a process for producing high-carbon, high-chromium stainless steel products of improved cold-working and cold-forming properties and especially of producing cold-drawn stainless steel bars, rods and wire of a uniform structure ensuring a minimum amount of breakage and waste in the cold drawing.

50 Referring now more particularly to the practice of my invention, I improve the cold-working properties of high-carbon, high-chromium stainless steels by a heat-treatment comprising successive quench-hardening and annealing operations, respectively. To effect a hardening of the metal, I heat it to a temperature high enough to

ensure, within practical limits, that a maximum breakdown of carbide striations occurs; after which, I cool the metal rapidly in oil, water or air. Following these operations, carbides are found to exist in well dispersed globular form interspersed in a uniform and refined grain structure. I then anneal the metal by heating it through the critical range and thereafter slowly cooling it back through the critical range. Annealing does not destroy the effect of thorough metal carbide distribution brought about by the previous hardening operation. It does, however, considerably soften the steel to permit subsequent ready cold-working or cold-forming. It can be cold-worked more readily than steels heat-treated in accordance with practices heretofore employed in the art. Moreover, the grain is more uniform and there is very much less breakage in the cold-working operation.

As illustrative of the practice of my invention, I heat a coil of stainless steel rod material analyzing 16% to 22% chromium, 0.75% to 1.5% carbon, and the balance iron, to a temperature preferably within the range of 1800° F. to 1925° F. At such temperatures, carbides break up, recrystallization occurs. A metal soaking period of short duration at temperature, encourages a more complete readjustment of the metal crystalline structure. At the end of the heating operation, I remove the metal from the furnace while it is still at a temperature of 1800° F. to 1925° F. The metal is quench-hardened promptly, preferably by rapidly cooling in oil. Where desired, quenching in air may be effected. The hardened metal possesses a fine and uniform grain structure wherein metal carbides are well dispersed and are in globular form.

While I do not wish to be limited specifically to the range of temperatures given, I find the microstructures of metal pieces quench-hardened from temperatures somewhat below 1800° F. contain banded carbides to some degree, while those quench-hardened from temperatures substantially above 1925° F. show grain growth.

Following the hardening treatment, I anneal the hardened metal in a heat-treatment furnace, by heating it to a temperature of 1500° F. to 1600° F. From this temperature, the metal is cooled slowly in the furnace, preferably at a rate of approximately 25° F. per half-hour, to about 1200° F. from which it is air-cooled to room temperature. Annealing, in this case, brings about a softening of the hard, uniform metal. Carbides remain dispersed in globular form. It can be seen, therefore, that the hardening operation is carried out primarily to lend refinement to the metal, while the annealing operation serves to soften the refined metal. I find the metal to be far less brittle than if the hardening operation had been omitted.

After my sequential hardening and annealing steps, I find the metal to be in ideal condition for cold-working. In cold-drawing high-carbon stainless steel rods of the type described into rods and wire, I subject the metal to alternate cold-drawing and annealing operations until the metal is reduced to final form. Preferably, the annealing is conducted in a controlled non-oxidizing atmosphere; otherwise, the annealing treatment is followed by a pickling operation to remove the anneal scale prior to a further cold-drawing operation. The annealing operations relieve stresses in the metal incurred by cold-working. The finished metal then is ready for additional treatment or ready for particular use. It is of good length

and of uniform quality. A minimum number of breaks occur in the drawing.

For example, in drawing hot-rolled rod stock of $\frac{21}{64}$ inch diameter, and analyzing 17.0% chromium, 1% carbon and the remainder iron, into wire of 0.284 inch diameter, a first draw to 0.313 inch was employed with a subsequent annealing treatment. In total reduction, the wire broke only three times. According to prior practice, as many as fifty breaks commonly are encountered. These, of course, result in delay and a product of inadequate length. Moreover, with prior methods, as many as six to eight intermediate annealing operations are required, in order to achieve a reduction of this consequence in such a stainless steel, while my process requires but one or two intermediate anneals. Moreover, my finished wire is stronger, tougher, and more serviceable than heretofore known products because of improved grain structure.

Thus, it will be seen that there has been provided in this invention an art of working high-chromium stainless steel alloys of high-carbon contents, by which the various objects hereinbefore noted, together with many thoroughly practical advantages, are successfully achieved. Also, it will be seen that the heat-treating aspect of my invention as applied to high-carbon stainless steels of the class described, enables them to withstand various cold-working and cold-forming operations such as straightening, bending, drawing, sectional reduction or the like.

Aside from the many practical and economical operational advantages of my invention, cold-worked products fashioned in accordance with my process are of superior quality. They possess fine and uniform grain structure; flaws, blemishes, tears and working defects, accordingly, being at a minimum. The products are tough, hard and strong, and possess improved resistance to corrosion and abrasion.

While as illustrative of the practice of my invention, high-chromium, high-carbon stainless steels comprising 16% to 22% chromium and 0.75% to 1.5% carbon are specifically described, good results are achieved in similar stainless steels, even where the chromium and carbon contents are extended somewhat.

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 illustrative, and not in a limiting sense.

I claim:

1. In preparing for cold-working a previously hot-worked hypereutectoid stainless steel containing at least 16% chromium and 0.75% carbon which is hardenable by heat-treatment, the art which includes, quench-hardening the same from a temperature of 1800° F. to 1925° F., and then annealing the hardened metal at a temperature of 1500° F. to 1600° F.

2. In the cold-working of hot-worked high-chromium hypereutectoid alloy stainless steel of high-carbon content, comprising 16% to 22% chromium and 0.75% to 1.5% carbon, the art which includes, quench-hardening said metal from a temperature of at least 1800° F., annealing the hardened metal at a temperature of 1500° F. to 1600° F., pickling the same, and cold-working said annealed and pickled metal.

3. In the production of a cold-drawn, high-chromium hypereutectoid stainless steel alloy of high-carbon content comprising 16% to 22%

chromium and 0.75% to 1.5% carbon, the art which includes hot-rolling the metal, quench-hardening said hot-rolled metal from a temperature of at least 1800° F., annealing the hardened metal in a non-oxidizing atmosphere and at a temperature of 1500° F. to 1600° F., and cold-drawing said annealed metal.

4. In the cold-working of hypereutectoid hot-worked stainless steel comprising 16% to 22% chromium and 0.75% to 1.5% carbon content, the steps which include, heating the same in a suitable furnace to a temperature of 1800° F. to 1925° F. to recrystallize the metal, rapidly cooling the metal to harden the same, softening the metal by annealing it at a temperature of at least 1500° F., and then cold-working the same.

5. In the cold-working of a hypereutectoid previously hot-worked stainless steel comprising 16% to 22% chromium and 0.75% to 1.5% carbon, the art which includes, heating the metal in a suitable furnace to a temperature of 1800° F. to 1925° F. and then rapidly cooling the metal to harden the same, heating the hardened metal in a suitable furnace to a temperature of 1500° F. to 1600° F. and slowly cooling said metal to sub-

stantially 1200° F. to anneal the same, and cold-working the annealed metal.

6. In the production of cold-drawn hypereutectoid rod or wire comprising 16% to 22% chromium and 0.75% to 1.5% carbon, the art which includes, heating hot-rolled bar or rod stock in a suitable furnace to a temperature of 1800° F. to 1925° F., and rapidly cooling said stock to harden the same, reheating the hardened stock in a suitable furnace at a temperature of 1500° F. to 1600° F. and slowly cooling said stock to substantially 1200° F. to anneal the same, and finally cold-drawing the annealed stock into rod or wire.

7. In the production of cold-drawn hypereutectoid rod or wire comprising 16% to 22% chromium and 0.75% to 1.5% carbon, the art which includes, quenching hot-rolled bar or rod stock from a temperature of 1800° F. to 1925° F., re-heating and annealing the stock at 1500° F. to 1600° F., and thereafter subjecting the annealed metal alternately to cold-drawing and annealing operations.

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