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METHOD OF ROLLING STAINLESS STEEL AND PRODUCT THEREOF

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This application is a continuation in part of my co-pending application Serial No. 645,637 filed December 3, 1932, and entitled Non-corrosive alloy, and the invention relates to rolling, forming, and polishing of stainless steel and to certain products or articles fashioned therefrom.

Among the objects of my invention are the production in a simple, direct and economical manner of rustless iron or steel sheet, strip, bars, rods, wire, and the like of a fine even grain which are strong, durable, heat-resistant and corrosion-resistant; which possess high tensile strength, and high impact value; which lend themselves to hot and cold working, hardening, polishing, and the like; and which are highly resistant to decarburization and grain growth under the many conditions of fabrication and use.

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

As conducive to a clearer understanding of certain features of my invention it may at this point be noted that in heretofore known and/or used corrosion-resisting ferrous alloys, either the ferritic rustless alloys of the iron-chromium group or the austenitic iron-chromium-nickel group, many highly desirable characteristics are achieved. These alloys are durable, strong, and tough; they may be worked either cold or hot from strip, sheet or bar stock to give products or articles of desired size and shape; they are resistant to the corrosive effects of atmospheric conditions as well as to many acids, alkalies and salts, and, finally, are resistant to the effects of high temperatures, resisting discoloration and scaling while retaining their physical characteristics, strength, toughness and durability.

In heretofore known and/or used stainless iron or steel products of the class indicated products of no one composition, however, are equally possessed of all of the beneficial charactertistics outlined above. Thus, for example, on the one hand a product having a chromium content near the lower limit for commercial rust resisting alloys (about 12%) lends itself to both hot and cold working, may be heat-treated to give a fair range of hardness, strength, and impact resistance, and is not particularly susceptible to decarburization and grain growth. The alloy, however, is not qualified for resistance to severely corrosive conditions, for extreme high temperature duty, and especially for high temperatures in corrosive media; which characterizes the iron-chromium alloys of higher chromium contents.

Similarly, on the other hand an iron-chromium product having a chromium content near the upper commercial limit for rustless ferrous alloys (about 27 to 30%) although highly resistant to corrosion, and resistant to discoloration and scaling at high temperatures, suffers in workability and ductility. In addition, such a product in its manufacture tends toward decarburization and surface grain growth with a resultant roughening of the surface of the metal and the formation of minute checks and pits. It does not lend itself to hardening by heat-treatment, and such physical characteristics as tensile strength and impact resistance are limited. It is difficult to machine and must be carefully handled in both hot and cold forming operations to ensure a satisfactory product. It possesses a somewhat coarse grain tending toward growth, under continued use at high temperature thus causing brittleness, low impact, and low fatigue resistance.

Likewise, iron-chromium-nickel stainless steel sheet, strip, wire, and the like, although ductile and workable (both hot and cold), readily weldable and heat and corrosion resistant, are not hardenable by heat-treatment and are subject to decarburization and surface grain growth in manufacture as well as grain growth in use at high temperature.

One of the objects of my invention is the production, in an inexpensive and efficient manner, of corrosion resistant plate, sheet, strip, wire, and the like of uniform fine grained texture which are less subject to decarburization and grain growth, brittleness and fatigue than in the case of heretofore known products; which are of improved workability over a wider range of chromium contents than for the products described above; and which, for the ferritic alloys, lend themselves to increased maximum hardening by heat-treatment and hardening by heat-treatment throughout a wider range of chromium content giving an article or product of greater strength which is more durable and of a higher impact value than in heretofore known and/or used products of the class indicated.

Referring now more particularly to the practice of my invention, to iron, preferably of low-carbon content, there is added an alloying element or alloying elements such as chromium (or chromium and nickel) with or without supplementary amounts of molybdenum, tungsten, vanadium, copper and the like, together with

small amounts of nitrogen giving a corrosion-resisting ferrous alloy of fine even grain structure which is especially resistant to decarburization and grain growth in subsequent working of ingots, blooms, slabs and billets into plate, sheet, strip, bars, rods, wire and the like as indicated hereinafter. The evenness of grain is useful in minimizing directional properties in plate, sheet, strip, bars, rods and wire where the total extent of reduction is over about 50%. It also is beneficial in cold-rolled sheet and strip even where the amount of the total cold reduction is in excess of about 35%, the cold-working itself to some extent aiding in the elimination of directional effects.

Preferably the proportions of ingredients added are such as to give a stainless steel product analyzing approximately 10% to 30% chromium, .06% to .30% carbon, and over .06% but under .20% nitrogen for the ferritic iron-chromium metal (or chromium up to 30%, nickel up to 30%, carbon below .30%, and nitrogen greater than .06% but less than .20% for the austenitic iron-chromium-nickel metal). The particular quantity of the alloying metals together with the precise amount of carbon and nitrogen present are largely determinant of the physical characteristics of the products as will appear more fully hereinafter. A nitrogen content in excess of .06% and preferably in excess of .07% is necessary to impart the desirable characteristics to the products while a nitrogen content of .20% or over is likely to result in unsoundness and other gas defects. Ordinarily best results are achieved where the nitrogen content is greater than about .07% but less than about .13%, say approximately .09%.

The hot working characteristics of the metal are not adversely affected by the presence of nitrogen, the alloy lending itself to forging, upsetting, swaging and like hot operations, while the cold-working characteristics such as beading, spinning and deep-drawing are somewhat improved for all chromium (or chromium and nickel) analyses; the improvement in deep-drawing characteristics being particularly improved for a chromium content of 16% to 20%.

In fact, as a result of the resistance to decarburization advantage may be taken of higher working temperatures in processing ingots to billets, sheet, strip and bars, either by hot-working or by a combination of hot and cold-working operations, without resultant decarburization, surface grain growth, and generally coarse structure. The absence of decarburization and surface grain growth aids materially in producing a smooth bright surface which lends itself to easier polishing, thereby effecting important economies in this costly operation.

The properties conveyed by the nitrogen content are in some respects similar to the well known properties resulting from the use of a small increased amount of carbon without, however, the attendant undesirable effects of carbon on corrosion resistance and without decarburization and surface grain growth. In addition, it seems that the presence of nitrogen increases the solid solubility of carbon in the metal at temperatures above the critical point with a resultant more uniform dispersion of carbides in the metal, as martensite, upon cooling to room temperature.

As indicated above, the products are of a fine, even grain structure. An even, or uniform, grain structure is one which is less susceptible to the segregation of carbides. An even grain structure is particularly beneficial in such hot-worked and cold-worked products as plate, sheet, strip, bars and rods because there is a minimum of resultant directional properties. The freedom of these products from the usual striated or fibrous character found in heretofore known products is a very important characteristic. Especially is this true where the products such as sheet and strip are subjected to severe cold-forming operations as in deep-drawing. Products of a fibrous or striated character result in non-uniform forming and frequently in tearing and splitting of the metal.

In addition to the even grain structure, the products are especially resistant to decarburization and surface grain growth, this latter feature becoming increasingly important in products of the higher chromium contents and especially those of a chromium content between 16% and 20%.

Flowing from these characteristics are many practical advantages. Objectionable general grain growth as well as decarburization and surface grain growth of the products of the higher chromium contents are appreciably decreased. The products are more ductile, more workable and for the ferritic iron-chromium products, lend themselves to hardening by heat-treatment over a wider range of chromium content than in heretofore known rustless products or manufactures of the kind indicated. Cold forming operations, such as blanking, stamping, and especially deep-drawing, are considerably improved while hot forming operations may be successfully carried out over a wider range of temperatures. Likewise, the tensile strength of the products may be appreciably increased throughout a broader chromium range. So also, may the impact resistance of the lower chromium products be increased.

Furthermore, as a result of the fine grain structure and increased resistance to grain growth mentioned above, the products more readily lend themselves to welding and, in addition, give a weld of finer grain structure and hence one that is more reliable than in heretofore known products of the class indicated.

In addition to the many highly beneficial characteristics outlined above, the heat-resisting characteristics of the products are considerably improved over heretofore known and/or used products of the class indicated since resistance to objectionable grain growth is bettered as more particularly pointed out above.

Other characteristics of stainless steel products of the class indicated, such as resistance to corrosive effects of acid, alkaline and salt solutions are fully retained and, as a result of the finer grain structure, are substantially improved.

Thus it will be seen that there has been provided in this invention stainless steel or rustless iron and steel products in which the various objects hereinbefore noted together with many thoroughly practical advantages are successfully achieved. It will be seen that the physical characteristics of these products are greatly improved; that these improved characteristics permit many savings in manufacture and use heretofore unrealized; and that the useful field of application of these products is appreciably broadened.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiment hereinbefore set forth, it is to be understood that all matter described

herein is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .20 per cent but over .06 per cent, and the balance iron and then hot-rolling said products to form sheet or strip free from decarburization and surface grain growth effects by virtue of said nitrogen content.

2. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .13 per cent but over .07 per cent, and the balance iron, then hot-rolling said products to form sheet or strip free from decarburization and surface grain growth effects by virtue of said nitrogen content, and then cold-rolling this hot-rolled sheet or strip.

3. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .20 per cent but over .06 per cent, and the balance iron, then hot-rolling said products to form sheet or strip free from decarburization and surface grain growth effects by virtue of said nitrogen content, cold-rolling this hot-rolled sheet or strip, and then polishing this cold-rolled sheet or strip thereby obtaining a mirror-like surface.

4. In the production of stainless steel rods or wire substantially free of surface defects, the art which includes, re-heating a billet comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .13 per cent but greater than .07 per cent, and the balance iron, and then rolling and drawing said product forming rods or wire free from decarburization and surface grain growth effects by virtue of said nitrogen content.

5. In the production of stainless steel rods or wire substantially free of surface defects, the art which includes, re-heating a billet comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .20 per cent but greater than .06 per cent, and the balance iron, then rolling and drawing said product forming rods or wire free from decarburization and surface grain growth effects by virtue of said nitrogen content, and then polishing this rod or wire to achieve a desired lustrous surface.

6. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets comprising chromium 16 per cent to 20 per cent, carbon .06 per cent to .30 per cent, nitrogen in an amount greater than .06 per cent but less than .20 per cent with the balance principally iron, and then hot-rolling said products forming thereby sheet or strip free from decarburization and resultant surface grain growth and minute pitting.

7. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets comprising chromium 16 per cent to 20 per cent, carbon .06 per cent to .30 per cent, nitrogen in an amount greater than .06 per cent but less than .20 per cent with the balance principally iron, then hot-rolling said products forming thereby sheet or strip free from decarburization and resultant surface grain growth and minute pitting, and cold-rolling this sheet or strip to achieve a desired bright shiny surface.

8. In the production of stainless steel sheet or strip substantially free of surface defects, the art which includes, re-heating and then hot-rolling ingots, blooms, slabs or billets comprising chromium 16 per cent to 20 per cent, carbon .06 per cent to .30 per cent, nitrogen in an amount greater than .07 per cent but less than .13 per cent with the balance principally iron forming thereby sheet or strip free from decarburization and resultant surface grain growth and minute pitting, cold-rolling this hot-rolled sheet or strip, and then polishing the cold-rolled product to achieve a mirror-like surface.

9. In the production of stainless steel sheet or strip for use in the fabrication of pressed, bent, stamped or deep-drawn articles, the art which includes, re-heating and then hot-rolling ingots, blooms, slabs or billets comprising chromium 10 per cent to 30 per cent, nitrogen greater than .06 per cent but less than .20 per cent and the balance substantially iron to form sheet or strip substantially free from decarburization and surface grain growth effects.

10. In the production of stainless steel sheet or strip for use in the fabrication of pressed, bent, stamped or deep-drawn articles, the art which includes, re-heating and then hot-rolling ingots, blooms, slabs or billets comprising chromium 16 per cent to 20 per cent, carbon .06 per cent to .30 per cent, nitrogen greater than .06 per cent but less than .20 per cent and the balance substantially iron to form sheet or strip substantially free from decarburization and surface grain growth effects.

11. In manufactures of the class described, sound stainless steel sheet or strip free from decarburization and resultant coarse surface grain texture and minute checks and pits comprising chromium 10 per cent to 30 per cent, nitrogen greater than .06 per cent but less than .20 per cent and the balance substantially iron said sheet and strip being hot-rolled from an ingot, bloom, slab or billet.

12. In manufactures of the class described, highly polished cold-rolled stainless steel sheet or strip free from decarburization and resultant coarse surface grain structure and pitting, comprising chromium 10 per cent to 30 per cent, nitrogen over .06 per cent but under .20 per cent and the balance principally iron, said sheet or strip being rolled from hot-rolled sheet or strip.

13. In manufactures of the class described, highly polished, cold-drawn stainless steel rods or wire free from decarburization and resultant coarse surface grain structure and pitting, comprising chromium 10 per cent to 30 per cent, nitrogen over .06 per cent but under .20 per cent and the balance principally iron, said rods or wire being drawn from hot-rolled wire, rod or coils.

14. In manufactures of the class described, deep-drawn stainless steel articles fashioned from sheet or strip of fine grain texture free from decarburization and surface grain growth effects comprising chromium 10 per cent to 30 per cent, nitrogen greater than .06 per cent but less than .20 per cent and the balance iron.

15. In manufactures of the class described, pressed or stamped stainless steel articles fashioned from sheet or strip of fine grain texture

and free from decarburization and surface grain growth effects comprising chromium 10 per cent to 30 per cent, nitrogen greater than .06 per cent but less than .20 per cent and the balance substantially iron.

16. In manufactures of the class described, highly polished articles fashioned of re-heated and worked stainless steel free from decarburization and surface grain growth effects comprising chromium 10 per cent to 30 per cent, nitrogen over .06 per cent but under .20 per cent, and the balance iron.

17. In manufactures of the class described, highly polished pressed, bent, stamped, or deep-drawn stainless steel articles fashioned of sheet or strip of fine grain texture free from decarburization and surface grain growth effects comprising chromium 10 per cent to 30 per cent, nitrogen greater than .07 per cent but less than .13 per cent and the balance of the metal substantially iron, said sheet or strip being rolled from hot-rolled sheet or strip.

18. In the production of stainless steel plate, sheet or strip substantially free of surface defects, the art which includes, heating or re-heating ingots, blooms, slabs or billets, comprising chromium 10 per cent to 30 per cent, nitrogen in an amount less than .13 per cent but over .07 per cent, and the balance iron and then hot-rolling said products to form plate, sheet or strip free from decarburization and surface grain growth effects by virtue of said nitrogen content.

19. In manufactures of the class described, sound stainless steel plate, sheet or strip free from decarburization and resultant coarse surface grain texture and minute checks and pits comprising chromium 10 per cent to 30 per cent, nitrogen greater than .07 per cent but less than .13 per cent and the balance substantially iron, said plate, sheet or strip being hot-rolled from an ingot, bloom, slab, or billet.

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