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ALLOY AND METHOD

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This application is a companion to my copend-
ing application, Serial No. 546,926, filed of even
date herewith and entitled Alloy and method,
and the invention relates to chromium-nickel
stainless steels and to a method for conditioning
the same for hardening as well as to pre-hardened
and precipitation-hardened products or manu-
factures thereof.

An object of my invention is the provision of
chromium-nickel stainless steels that are suited
to hardening at low temperature.

Another object is the provision of a commer-
cially practical method for conditioning such
steels wherein, by annealing, the alloys are ren-
dered highly suitable for a wide variety of fabri-
cating operations and, in which method, by sub-
sequent double hardening treatment, the alloys
are transformed and precipitation-hardened in a
thoroughly effective manner.

A further object of my invention is the pro-
vision of chromium-nickel stainless steel prod-
ucts which are precipitation-hardened from soft,
formable and machinable condition, and which
as hardened possess high tensile and compressive
values and have reasonably high ductility to-
gether with freedom from substantial directional
effects which characterize the usual cold-rolled
chromium-nickel stainless steel sheet and strip.

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

The invention accordingly consists in the com-
bination of elements, composition of materials,
and conditions of treatment, and in the various
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 following claims.

As conducive to a clearer understanding of
certain features of my invention, it may be noted
at this point that stainless steels are defined as
low-carbon steels which comprise 10% to 35%
chromium, with or without nickel, and with or
without supplemental additions of copper, man-
ganese, silicon, cobalt, molybdenum, tungsten,
vanadium, titanium, columbium, sulphur, and the
like, for special purposes, and a remainder which
is substantially all iron. The carbon content
may range from 0.03% to 0.20%, or more where
desired.

There are among the stainless alloys certain
chromium-nickel stainless steels, particularly
those which are classifiable with the more com-
monly known 18% chromium—8% nickel grades,
which remain stably austenitic at room tempera-
tures after quenching, and in no manner are

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hardenable by heat treatment. These steels are
work-hardenable, however, which in many in-
stances is not a satisfactory property for the pro-
vision of hardened products. Because of other
more favorable properties, however, the steels are
in widespread demand for fabrication into prod-
ucts by such methods as hot-working, cold-form-
ing, machining, punching, drilling, drawing or
spinning. A further difficulty, however, arises as
a result of rolling or drawing the metal; trouble-
some directional effects are notable especially a
loss in compression along the direction of rolling
or drawing. After fabrication, the steels are put
into use either in soft strain-relieved condition,
or in the work-hardened condition when feasible.

Some effort has been made in the prior art to
provide stainless steels which are hardenable by
heating to a temperature low enough to avoid
or minimize oxidation and undue distortion. This
effort has been to realize a precipitation, at this
relatively low temperature, of a critically dis-
bursed phase. An analogy presents itself in the
case of the well-known aluminum alloys.

For example, in the prior art, it has been sug-
gested to use titanium or columbium as harden-
ing agents for chromium-nickel stainless steels.
Such precipitation hardenable alloys have been
disappointing either because the expected results
are not actually obtained, or because of diffi-
culties encountered in obtaining products of con-
sistently uniform and reliable properties. More-
over, titanium is difficult to control in amount
due to erratic recovery in the steel melting op-
eration, and presents a very serious difficulty in
the case of products to be welded because of the
loss of titanium during the welding operation.

An outstanding object of my invention accord-
ingly is the provision of chromium-nickel stain-
less steels which lend themselves to ready fabrica-
tion in sheet, strip, bar, wire and other forms
into a host of products which subsequently are
hardened at low temperature with minimum scal-
ing and discoloration, and without warping, which
steels and products fashioned thereof are char-
acterized by other desirable properties in both
pre-hardened and hardened condition.

Referring now more particularly to the practice
of my invention, I find that by closely correlating
the chromium and nickel contents of the steel,
and in addition including the ingredient copper
in critical amounts, a stainless steel which is
susceptible to precipitation-hardening is had.
This result is new and surprising. My stainless
steel comprises about 16.5% to approximately

18.5% chromium, nickel in an approximate range of 4.75% to 5.60%, copper in amounts between about 3.5% and approximately 5.0%, carbon preferably not exceeding about 0.1%, and the remainder substantially all iron. Also I find that certain further benefits are had by including in the composition one or more elements of the group consisting of beryllium from traces up to around 0.25%.

By subjecting my stainless steels to a special conditioning treatment the alloys are found to retain a characteristic high temperature copper-soluble austenitic structure down to about room temperature. These alloys then are hardened by transformation and the precipitation of copper from solid solution.

The special conditioning treatment of my invention includes holding wrought or cast stainless steel of the particular composition just described within a temperature range of about 1700° F. extending up to around 2000° F., a temperature of approximately 1800° F. being preferred. This treatment serves to place the metal in an austenitic copper-soluble condition which is retainable down to at least about room temperature. The period of holding at high temperature is not too critical, a period of about ½ hour is preferred. Usually for this treatment the metal is adjusted to temperature in a suitable heat-treating furnace and is held therein at temperature for the necessary period. I then quench the metal as in air, oil or water to around room temperature, as at quenching rate of about 400° F. per minute, and thus provide an annealed or pre-hardened copper-soluble alloy which retains an austenitic structure much in a manner as do 18% chromium-8% nickel austenitic stainless steels after similar treatment. As quenched, the alloys are reasonably ductile, have good directional qualities and hardnesses usually below about Rockwell B100. In addition they are formable and machinable, one or more of which properties contribute in making it possible to fabricate the metal at this point into any of a wide variety of pre-hardened products.

From the quenched or pre-hardened chromium-nickel-copper stainless steels, which now are precipitation hardenable by subsequent treatment to be described, I provide products in such forms as bars, wire, rounds, sheet, strip or plate. Also, I may provide shapes which are more intricate, illustratively trim, structural members or the like as for the aircraft industries, cold-headed bolts and screws requiring hard shanks, shafting, surgical instruments, valves and valve seats. In all of these advantage is taken of excellent working and forming properties of the pre-hardened metal such as cold-forming, upsetting, drawing, spinning, machining, stamping, punching, cutting, and the like which are consistent with the properties of the metal.

After the pre-hardening treatment and fabricating operation have been achieved, I subject the chromium-nickel-copper stainless steel to either one of two preliminary heat-exchange hardening treatments. As a first and preferred alternative, I reheat the metal, illustratively in the same heat-treating furnace employed in the high temperature treatment, so as to bring the transformation point of the austenitic to the ferritic condition above ordinary room temperature. In this treatment the metal is held at 1250-1600° F., preferably at about 1400° F., from about five minutes up to six hours or more. A three-quarter hour period as an approximate figure is found

to be most practical and, therefore, is preferred. Following the reheating stay the metal is cooled as in air or water with the result that transformation does occur above room temperature.

The transformation noted produces a chromium-nickel martensitic structure and partial precipitation of a copper-rich phase. Hardnesses after this transformation vary in or near the range of Rockwell C33 to C37 depending upon the exact composition and the particular conditions of treatment within the limits defined herein.

As an alternative, instead of reheating in the manner described, I employ a preliminary hardening treatment which involves cooling the pre-hardened metal to effect transformation below usual room temperatures. In the practice of this alternative, I hold the pre-hardened metal, as in fabricated condition, in a suitable cooling compartment, or the like, at cooling temperatures of about (+) 32° F. to (-) 100° F. or lower for such periods of time as to effect transformation. Usually at least ½ hour at cooling temperature, as in dry ice and/or acetone for the cooling medium, is preferred.

When transformation has been achieved either through reheating and quenching or by low temperature conditioning as described, the alloys then are ready for positive precipitation-hardening which as an operation forms a second step of my hardening treatment. In performing this second step I heat the alloys, as in the form of fabricated products, within a temperature range of about 850° F. to approximately 950° F., preferably at about 900° F., and hold the same at temperature for about ½ hour. The time of treatment, however, may vary from approximately fifteen minutes to two hours without excessive under-aging or over-aging. This treatment serves to give substantially complete precipitation of a copper-rich phase throughout the metal grains. The copper-rich precipitate is not visible under an ordinary light microscope, but I find that it can be photographed with the aid of an electron microscope. It is this precipitated copper-rich phase which gives the hardness.

Following the heating at hardening temperature the steels and products thereof are advantageously quenched to room temperature. In the hardened condition, as after quenching, the alloys display high values both in tension and compression, high yield strength, good directional qualities, a reasonable degree of ductility, and good hardness, this latter usually falling in or near the range of Rockwell C37 to C44. The alloys and products thereof also are quite resistant to salt spray and to corrosion in ordinary atmosphere, both before and after hardening.

As a further feature of my invention I provide welded joints and welded products from the chromium-nickel-copper stainless steels disclosed herein and treat the metal, including the weld, in accordance with my initial high temperature annealing and subsequent double-hardening treatments. In order to afford a beneficial source of weld addition metal, I also provide weld rods which include as filler or deposit metal the chromium-nickel-copper alloy metal disclosed.

My stainless steels are weldable by arc, gas, spot, or other welding methods without substantial loss of copper, which is an important advantage remembering that alloys which contain aluminum, titanium, or the like to promote the precipitation-hardening effect suffer a loss

of the hardening material in the welding operation.

Of the broad group of chromium-nickel-copper stainless steels noted hereinbefore I prefer in particular those which include, in approximate percentages, 16.5% to 17.5% chromium, 4.85% to 5.35% nickel, 3.60% to 4.35% copper, and carbon up to 0.08%. To illustrate certain properties which are obtainable with this more specific group of alloys, a table is given below. All values given for annealed condition refer to one-half hour treatment at 1800° F. followed by water-quenching, while the values noted for hardened condition refer to this form of annealing treatment followed by three-quarter hour treatment at 1400° F. and water-quenching coupled with one-half hour treatment at 900° F. and water-quenching.

Table

	Rockwell Hardness	Brinell Hardness	Ult. Tens. Str., p. s. i.	0.2% Yield Str., p. s. i.	Elong. 2", Per-cent	Reduction of Area, Percent
Annealed.....	B90-100	150-240	120,000 to 140,000	30,000 to 45,000	20 to 30	40 to 60
Hardened.....	C39-44	372-415	180,000 to 200,000	160,000 to 180,000	8 to 15	35 to 55

The hardened chromium-nickel-copper stainless steels which include beryllium, as from traces up to around 0.25%, are characterized by higher ultimate tensile strength, greater yield strength and higher final hardnesses than the figures given above. Such steels are especially suitable for cutting tools, dies, hard balls, and the like. The beryllium contributes as a second precipitation-hardening agent to the hardening effect of the copper.

Thus it will be seen that there is provided in this invention a chromium-nickel stainless steel suited for hardening by heat treatment, as well as a method of precipitation-hardening these steels, in which the various objects hereinbefore noted together with many thoroughly practical advantages are successfully achieved. It will be seen that the method makes possible the provision from chromium-nickel stainless steels which can be cast, welded, or wrought, or subjected to a number of forming, machining or fabricating operations, products which are hard yet which are substantially free of directionality and possess a reasonable amount of ductility. In addition the hardened steels and articles or products thereof possess high ultimate tensile and compressive values and high yield strength.

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

I claim:

1. In a method of conditioning low-carbon chromium-nickel stainless steel, providing a steel containing about 16.5% to 18.5% chromium, about 4.75% to 5.60% nickel, and including copper between about 3.5% and 5.0%, and the remainder substantially all iron; treating said steel within a temperature range of about 1700° F. to 2000° F. and quenching the same to provide a copper-soluble austenitic condition stable down to at least room temperature; transforming the alloy; and heating the transformed alloy within a temperature range of 850° F. to 950° F. to precipitate copper and obtain an increase in the alloy hardness.

2. In a method of precipitation hardening low-carbon chromium-nickel stainless steel, providing a steel containing about 16.5% to 18.5% chromium, about 4.75% to 5.60% nickel, copper between about 3.5% and 5.0%, and the remainder substantially all iron; rendering said alloy in a stable austenitic condition at about room temperature through suitable heating and quenching; then heating said alloy within a temperature range of about 1300° F. to 1500° F. and quenching the same to effect transformation thereof; and finally heating the transformed alloy within a temperature range of about 850° F. to 950° F. to precipitate copper and obtain an increase in the alloy hardness.

3. In a method of precipitation-hardening low-carbon chromium-nickel stainless steel, providing a steel containing about 16.5% to 18.5%

chromium, about 4.75% to 5.60% nickel, copper between about 3.5% and 5.0%, and the remainder substantially all iron; rendering said alloy in a stable austenitic condition at about room temperature with a substantial amount of the copper in solution through suitable heating and quenching; then cooling said alloy to below a temperature of at least 32° F. for transforming the same; and finally heating the transformed alloy within a temperature range of about 850° F. to 950° F. to precipitate copper and obtain an increase in the alloy hardness.

4. A hardened chromium-nickel stainless steel containing about 16.5% to 18.5% chromium, about 4.75% to 5.60% nickel, copper between about 3.5% and 5.0%, carbon not exceeding about 0.1%, beryllium from traces up to around 0.25%, and the remainder substantially all iron, said alloy being characterized by a precipitated copper-rich and beryllium-rich phase throughout the metal.

5. A hardened chromium-nickel stainless steel comprising about 16.5% to 18.5% chromium, about 4.75% to 5.60% nickel, copper between about 3.5% and 5.0%, carbon not exceeding about 0.1% and the remainder substantially all iron, said alloy being characterized by heating between temperatures of about 1700° F. to approximately 2000° F. and quenching to ensure a predominantly austenitic structure down to at least about room temperature, by transformation, and by heating within a temperature range of about 850° F. to approximately 950° F. to precipitate copper and obtain an increase in alloy hardness.

6. A hardened chromium-nickel stainless steel comprising about 16.5% to 17.5% chromium, about 4.85% to 5.35% nickel, copper between about 3.60% and 4.35%, carbon up to around 0.08%, and the remainder substantially all iron, said steel being characterized by heating at approximately 1800° F. and cooling to ensure a predominantly austenitic structure down to at least about room temperature, by heating at about 1400° F. and quenching, and by heating at approximately 900° F. to precipitate copper and obtain an increase in hardness.

7. Pre-hardened chromium - nickel stainless steel in the wrought or cast condition, comprising, about 16.5% to 18.5% chromium, 4.75% to 5.60% nickel, copper between about 3.5% and 5.0%, carbon not exceeding about 0.1%, and the remainder substantially all iron, said product being characterized by heating the metal between temperatures of about 1700° F. to approximately 2000° F. and quenching to ensure a predominantly austenitic structure down to at least about room temperature in which copper is present in solution.

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