

UNITED STATES PATENT OFFICE

2,553,706

STAINLESS STEEL SPRING

George N. Goller, Baltimore, Md., assignor to
Armco Steel Corporation, a corporation of Ohio

No Drawing. Application January 31, 1947,
Serial No. 725,712

3 Claims. (Cl. 148—31)

1

This application for patent is a companion to my application, Serial No. 725,713 of even date herewith entitled Spring and Method, and my copending applications, Serial Nos. 695,215, 695,216 and 695,217 all of September 6, 1946 and all entitled Stainless Steel and Method now Patents 2,505,762, 2,505,763 and 2,595,764 of May 2, 1950, and the present invention relates to resilient chromium-nickel stainless steel products, more especially to stainless steel springs and the like, and to a method for producing the same.

Among the objects of my invention is the provision of a simple, direct and thoroughly reliable method for producing hardened stainless steel springs, such as leaf, coil or wire springs, which method is highly practical and effective for achieving elastic properties including excellent values in tension and compression and high yield strength and high proportional limit of the springs so produced.

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

The invention accordingly consists in the composition of materials, features of products, in the several steps, and in 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 by way of general definition include 10% to 35% chromium, with or without nickel, and with or without supplemental additions of manganese, silicon, cobalt, molybdenum, titanium, vanadium, columbium, boron, zirconium, aluminum, sulphur, and the like, for special purposes, and a remainder which is substantially all iron.

It may also be noted that springs and other resilient metal products heretofore made of stainless steel, such as of the better known 18—8 (18% chromium, 8% nickel and the remainder iron) steels, have the highly valuable property of resisting corrosion in any of a great number of specific uses and in the presence of compositions or materials which ordinarily attack and corrode plain carbon steel springs.

A number of the heretofore available stainless steel springs, however, are not appreciably susceptible to hardening by heat treatment for developing the desired spring properties and thus are put into service in the relatively soft state or in the cold-work-hardened condition. The unhardened springs, however, quite often have a somewhat too low elastic limit, and an ultimate strength which also is too low. In many instances too the metal of the spring is not amenable to cold-working and gives rise to cracks and splits which lead to excessive losses in production. And further, there are times when sufficiently high

2

elastic properties are not achieved, where desired, by relying solely upon cold-working treatment for developing the properties.

Quench-hardenable springs which reach a substantially full hardness in response to annealing and quenching for developing desired elastic properties sometimes have heat scale and surface pits which for example come from the high annealing temperatures employed. In the hardened condition the metal is relatively difficult to form, sometimes so difficult that the springs advisedly are fabricated to substantially final shape and dimensions before the high temperature hardening heat treatment. The existence of heat scar and pits in the hardened metal usually is not tenable for such reasons as often being responsible for fatigue failure of the springs or poor appearance of the finished products. These surface imperfections, however, are more expensive and time consuming to remove after the metal has been hardened, especially should the problem of removal involve the performance of mechanical operations such as grinding, machining, or the like. The problem at times includes that of cleaning up the metal with minimum disturbance of dimensions which were established by fabricating the springs before the operation of hardening at high temperatures.

An object of my invention accordingly is the provision of strong and durable chromium-nickel stainless steel springs, hardened at low temperatures, and having highly developed elastic limit and high ultimate strength.

Referring now more particularly to the practice of my invention, I produce chromium-nickel-copper stainless steel springs having high elastic limit and great ultimate strength, using a treatment of the metal which includes the combination cold-working and low temperature copper-precipitating heat treatment for developing the elastic properties.

The springs which I produce contain, in approximate percentages, 16.5% to 18.5% chromium, from 2.85% to 5.60% nickel, 3.0% to 5.0% copper, up to 0.16% carbon and up to 0.13% nitrogen together not exceeding about 0.21%, and the remainder substantially all iron. Amounts of other elements may be present in the steel which do not materially impair the properties of the springs, illustratively beryllium from traces up to about 0.25% as a precipitation element.

In the more general class just given, the springs often contain carbon not exceeding about 0.10%, less than about 0.05% nitrogen, about 16.5% to 18.5% chromium, nickel about 4.75% to 5.60%, copper in amounts between about 3.0% and approximately 5.0%, and the remainder substantially all iron. The springs it will be observed are of a relatively low-carbon, low-nitrogen grade.

Where the springs are of the relative high-

carbon and/or high-nitrogen grade, they frequently contain 16.5% to 18.5% chromium, from 2.85% to 4.85% nickel, copper in amounts between about 3.0% and 5.0%, from 0.14% to 0.21% carbon and nitrogen in sum total, with at least one of the latter two elements further being within the respective ranges of 0.10% to 0.16% carbon and 0.05% to 0.13% nitrogen, and the remainder substantially all iron, the percentages given being approximate.

In producing springs in accordance with my invention, I usually hot work the metal, as from the form of billets to a satisfactory size for cold working and subject the metal, for example as rod, wire, plate, sheet or strip to an annealing treatment before actually effecting the cold-working operations which serve to assist in developing the spring properties. Where desired, as for minimum reheating of the metal, I carry out the steps of hot working directly as a part of the annealing treatment. The annealing itself advantageously includes heating the stainless steel within a temperature range of about 1700° F. to 2100° F., the optimum range being around 1800° F., and perhaps inclusive of a temperature so high as 2000° F. or more especially where the larger quantities of carbon are present in the steel. As a matter of convenience, I achieve the annealing in a suitable heat treating furnace, this by bringing the steel to annealing temperature and soaking the heated metal at temperature for a short period of time. This treatment serves to put the metal in an austenitic copper-soluble condition, with carbon also in solution, which is retainable down to at least about ordinary room temperature. I prefer to employ a soaking period of about one-half hour as applied to the annealing treatment. The length of the treatment time, however, is not too critical.

Following the annealing heat, I quench the steel as in air, oil or water and to about room temperature and thus provide soft, annealed alloy metal which retains a substantially austenitic structure. As quenched, the metal is reasonably ductile, and has hardness values which usually are so low as to below about Rockwell B-100. At this point I often resort to pickling or mechanical treatment such as grinding to remove any heat scar from the annealed metal surface.

In providing my stainless steel springs, I subject the metal to cold-working treatment, for example to at least one of the operations, rolling, drawing, or straightening, and preferably by beginning these operations from the soft condition achieved by the annealing. In employing cold-rolling in providing the necessary cold work, this treatment sometimes serves the additional function of reducing the metal to gauge which approaches or substantially corresponds to that of a desired finished spring product such as a flat spring. A standard rolling mill frequently is satisfactory for accomplishing the cold rolling work, as by the use of several passes. Likewise, when relying in part at least upon cold drawing for the cold work required, it often is convenient to draw the metal as from rod or wire to substantially finished gauge of a wire or coil spring. Where desired, of course, I use the cold-working treatment for producing cold worked wire, rods, sheet, strip and the like which are readily useful at some later time for making up the stainless steel springs.

The cold-working treatment to which I subject the stainless steel is sufficiently intense to

give anywhere from a mild to a heavy reduction. In general, the cold reduction amounts to about 5% to 80% or possibly 90% measured in terms of cross-sectional area of such shapes as wire. This same range usually is satisfactory as applied to percent reduction in area in reducing sheet or strip. A more extensive reduction without first repeating the anneal, frequently results in sharp loss of ductility and also internal fissure or "cupping" of the metal and consequent fracture. The diameter or thickness of the metal shape at the outset of cold working has some influence upon the maximum permissible amount of cold work. For wire having a diameter greater than that of approximately $\frac{1}{4}$ inch, or sheet or strip exceeding about $\frac{1}{4}$ inch in thickness, I prefer some 20% (even better about 35%) to 60% reduction by cold working, this extending up to about 80% for smaller gauges. The small gauge shapes usually develop even somewhat better elastic properties similar to those of plain carbon steel music wire. The straightening and/or bending operation which at times I employ for effecting the cold work, may replace or contribute to other forms of cold working, where desired, and may be slight or extensive.

Before subjecting the steel to my precipitation heat treatment, I usually fabricate the metal into springs or spring elements as a part of the cold-working treatment. In any event, during, or preferably following the cold-working treatment, the steel is given the precipitation heat treatment for further enhancing the elastic properties.

In effecting the precipitation heat treatment, I heat the cold-worked chromium-nickel-copper stainless steel, within a temperature range of about 800° F. to approximately 950° F., preferably to about 900° F., and hold the same at temperature for about one-half hour. The holding time, however, may vary from approximately fifteen minutes to two hours or more, usually without under treatment or over treatment. The treatment causes precipitation of a critically dispersed copper-rich phase which increases the elastic properties and hardness of the metal and products. The copper-rich precipitate usually is not visible under an ordinary light microscope.

Upon the precipitation of copper, I find advantage in quenching the stainless steel springs or the like (illustratively wire, sheet or strip for making the springs), this for example being in air, oil or water to about room temperature. In the quenched condition my stainless steel products display high ultimate strength, high yield strength, a high torsion modulus, and usually better direction properties as compared with cold worked austenitic 17% chromium-7% nickel stainless steel springs. My steel products are quite resistant to salt spray and to corrosion in ordinary atmosphere, both before and after the precipitation treatment. The metal emerges from the cold-working and precipitation heat treatment substantially free of heat scale and unwarping by heat at the low temperatures employed. I sometimes fabricate the precipitation heat treated wire, sheet or strip into springs or for example make this fabricated metal available for customer use.

By inspection of Tables I and II, an appreciation will be had of certain physical properties achieved in a chromium-nickel-copper stainless steel wire by the combined action of annealing, cold drawing, and precipitation heat treatment in accordance with my process. The infor-

mation appearing in the tables is based upon a steel which contains, in approximate percentages, 0.066% carbon, 17.29% chromium, 5.09% nickel, 3.90% copper, 0.73% manganese, 0.010% phosphorus, 0.009% sulphur, 0.47% silicon, and the remainder substantially all iron. The mechanical properties corresponding to condition R are representative of the soft, annealed metal wire, while those corresponding to condition A are representative of the precipitation heat treated wire after different amounts of cold reduction. The condition R more particularly was derived by holding the steel wire at an annealing temperature of about 1800° F. for ½ hour followed by quenching in water. The condition A was obtained by the same character of annealing as for condition R, but by following with cold drawing to the extent indicated, and then precipitation heat treating at about 900° F. for ½ hour and cooling in air.

Table I

Condition	Size (inches)	Per Cent Cold Drawn	Ult. Tens. Str., p. s. i.	.2% Yld. Str., p. s. i.	Prop. Lmt., p. s. i.	Elong. 2", Per Cent	Red. of Area, Per Cent	Rockwell Hardness
R.....	.250	0.0	115,000	36,000	19,000	40.0	65.0	B-82
A.....	.235	12.0	115,000	100,000	67,000	30.0	68.5	C-28
A.....	.224	20.0	149,000	134,000	76,000	14.0	67.0	C-37
A.....	.209	30.0	183,000	164,000	99,000	(1)	62.0	C-40
A.....	.193	40.0	217,000	200,000	148,000	6.5	59.0	C-43
A.....	.169	54.0	245,000	234,000	150,000	6.0	59.0	C-44
A.....	.158	60.0	258,000	250,000	172,000	4.5	56.0	C-48

¹ Specimens broke too near jaws to measure per cent elongation.

From the data in Table II below, it will be observed that slightly increased mechanical properties are had by treatment of somewhat smaller diameter wire from annealed condition, this as compared with the larger gauges noted in Table I.

Table II

Condition	Size (inches)	Per Cent Cold Drawn	Ult. Tens. Str., p. s. i.	.2% Yld. Str., p. s. i.	Prop. Lmt., p. s. i.	Elong. 2", Per Cent	Red. of Area, Per Cent	Rockwell Hardness
R.....	.156	0.0	120,000	65,000	34,000	40.0	68.0	B-80
A.....	.150	10.0	128,000	97,000	65,000	35.0	69.0	C-34
A.....	.141	20.0	165,000	145,000	80,000	14.0	62.0	C-40
A.....	.132	30.0	215,000	185,000	75,000	4.0	56.0	C-43.5
A.....	.122	40.0	227,000	197,000	93,000	3.5	53.0	C-43
A.....	.111	50.5	260,000	258,000	191,000	3.0	49.0	C-46
A.....	.100	60.0	260,000	258,000	195,000	4.0	50.0	C-47

The stainless steel springs which I achieve through the practice of my process, whether they be in the form of wire or flat springs as of compression, extension, torsion, elliptical or cantilever type, display high torsion modulus, high elastic limit and great ultimate strength, whenever occasions arise for use of any or all of the properties. Among the specific types of springs which I provide are for example those for precision instruments such as bombsights, speed indicators, weighing scales and navigation instruments, in which high elastic properties are required for exact and proper readings; and gun springs, lock springs, governor springs, and the like, which are to function while exposed to corrosive atmospheres. In a further illustrative category, I provide stainless steel coil springs or spring-motors, these for operating while under high stress. A still further illustrative group of my springs and products includes wire, rod or flat shapes as in the form of windshield wiper shafts, radio aerials, fishing rods and tackle, and knives illustratively with long blades, which

are to be exposed to flexing, pulling, twisting or the like.

When desired, for producing the springs or products such as sheet, strip and wire, I subject the steel to annealing at solution temperature and quenching to the soft annealed austenitic condition as hereinbefore described, and thereafter reheat the metal, this reheat being to within the approximate range of 1250° F. to 1600° F., and preferably to about 1400° F. I hold the steel at temperature for say a period of time ranging from five minutes to six hours or more. A three-quarter hour period or thereabouts usually is quite practical and thoroughly satisfactory, and therefore is preferred as the optimum holding time. Then, by quenching the steel as in air, oil or water, I achieve transformation and a preliminary hardening of the metal, this before introducing the cold reducing operations for developing the elastic properties. The transforma-

tion produces a copper-nickel martensitic structure and partial precipitation of a copper-rich phase.

In particular, the cold reduction to which I subject the transformed steel, usually ranges from a slight amount up to about 60% reduction

in cross-sectional area. After the cold reduction, I subject the steel to the precipitation heat treatment as hereinbefore described, this advantageously being at a temperature of about 800° F. to 950° F. and preferably around 900° F. The resulting products have many highly desirable elastic properties, though perhaps somewhat at the sacrifice of the tensile strength achieved where the preliminary hardening heat treatment is not included.

Thus it will be seen that in this invention there is provided a method of producing chromium-nickel-copper stainless steel springs, and products such as wire, sheet, strip, and the like for use in fabricating springs, in which the various objects hereinbefore noted together with many thoroughly practical advantages are successfully achieved. It will be seen that the method is amenable to rapid and efficient production and is well suited for the achievement of high elastic properties by low temperature treatment of the cold worked metal. It will also be appreciated that the resulting products are strong, tough, and

7 durable even in the sense of being resistant to corrosion.

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. Cold-worked and precipitation-hardened stainless steel wire, sheet and strip springs having a proportional limit of about 65,000 to 195,000 p. s. i. or more and containing in approximate percentages, 16.5% to 18.5% chromium, from 2.85% to 5.60% nickel, 3.0% to 5.0% copper, carbon up to 0.16% and nitrogen up to 0.13% together not exceeding 0.21%, and the remainder substantially all iron having been subjected to annealing at 1700° F. to 2100° F., cold-working 5% to 90%, and precipitation treatment at 800° F. to 950° F.

2. Cold-worked and precipitation-hardened steel springs having a proportional limit of about 65,000 to 195,000 p. s. i. or more and containing in approximate percentages, 16.5% to 18.5% chromium, from 2.85% to 5.60% nickel, 3.0% to 5.0% copper, carbon up to 0.16% and nitrogen up to 0.13% together not exceeding 0.21%, and the remainder substantially all iron, the steel having been subjected to annealing at 1700° F. to 2100° F., cold-working 5% to 90%, and precipitation treatment at 800° F. to 950° F.

2100° F., slight to excessive cold working, and to precipitation heat treatment at 800° F. to 950° F.

3. Cold-worked and precipitation-hardened stainless steel springs and the like having a proportional limit of about 65,000 to 195,000 p. s. i. or more and containing, in approximate percentages, 16.5% to 18.5% chromium, from 2.85% to 5.60% nickel, 3.0% to 5.0% copper, up to 0.16% carbon and up to 0.13 nitrogen, the carbon and nitrogen together not exceeding 0.21%, and the remainder substantially all iron, said steel having been subjected to annealing at about 1700° F. to 2100° F. and quenching, to preliminary hardening heat treatment and quenching, slight to extensive cold reducing not exceeding about 60% in cross-sectional area, and precipitation heat treating at about 800° F. to 950° F. for long enough time to increase the elastic properties.

GEORGE N. GOLLER.

REFERENCES CITED

The following references are of record in the file of this patent:

FOREIGN PATENTS

Number	Country	Date
375,792	Great Britain	June 20, 1932
375,793	Great Britain	June 20, 1932
431,469	Great Britain	July 1, 1935
495,562	Great Britain	Nov. 14, 1938