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COLD-WORKABLE STAINLESS STEEL AND ARTICLES

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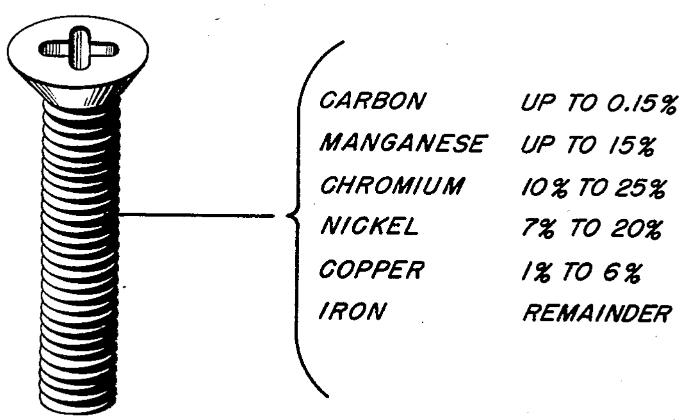

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COLD-WORKABLE STAINLESS STEEL AND ARTICLES

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My invention relates generally to austenitic cold-workable stainless steels, and more particularly concerns the production of cold-headed non-magnetic products fashioned of such steels.

An object of my invention is to provide a stainless steel and various cold-headed or cold-upset products formed of such steel which, while displaying all the advantageous properties characteristic of the steels including pleasing lustrous surface free from blemishes and high resistance to corrosion, at the same time respond nicely to cold-working with a minimum of work-hardening and in the substantial absence of excessive wear or breakage of forming dies, which can be worked to intricate surface detail, and which maintain their original substantially non-magnetic qualities.

Another object is to provide cold-headed or cold-upset products from stainless rod and wire such as snap-fasteners, bolts, rolled-screws, scrap-less nuts and the like, all with minimum number of operational steps, through cold-working manipulation in the absence of intermediate anneal.

Still another object is to provide a method of cold-working stainless steel products of the general character described, in the substantial absence of intermediate annealing and with but minimum wear on the simple forming equipment required.

Other objects in part will be obvious and in part more fully pointed out during the course of the following description.

Accordingly, my invention may be seen to reside in the combination of elements, and composition of ingredients, and in the various products of manufacture embodying the same, as well as in the several forming and manipulative steps, and the relation of each of the same to one or more of the others, the scope of the application of all of which is more fully set forth in the claims at the end of this specification.

The single view of the accompanying drawing discloses in perspective an illustrative embodiment of my invention, a Phillips screw produced in accordance with my practice.

As conducive to a more thorough understanding of my invention, it may be noted at this point that the austenitic chromium-nickel stainless steels are admirably suited for the production of a wide variety of headed or upset products, of which snap-fasteners, bolts, roll-threaded screws (of which the well-known Phillips screws are illustrative) scrapless nuts (those nuts formed by punching and expanding a hole in wire stock and thereupon tapping the same) are typical. Many are made from the well-known 18–8 chromium-nickel stainless steel. These various products are resistant to weather conditions, with display of little if any tendency towards corrosion, possess a nice surface appearance, both pleasing in effect and permitting working to close dimensional tolerances.

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Unfortunately, however, with these stainless steel alloys it is impractical to resort to severe cold forming practices such as cold-upsetting and cold-heading. The extreme rapidity with which the conventional austenitic chromium-nickel alloys harden when subjected to such cold-working severely restricts their use. Any resort to intermediate annealing heat-treatment greatly prolongs the manufacturing operation and materially increases production costs.

In large measure, it is this rapid work-hardening of the austentic chromium-nickel stainless steels that causes rapid increase in the power requirements necessary to bring about cold-deformation of the metal stock, i. e., working to desired products. The high loads thus interposed on the forming dies, increasing in substantial and non-linear gradient during the forming operation, causes rapid wear of these dies, attended by frequent breakage with consequent shut-down for repair or replacement. Illustratively, signal failure is encountered in the successful production of the recesshead screws, known as Phillips screws.

This general problem has been the subject of study for some time and a partial, but by no means entirely satisfactory, solution of the problem has been had by increasing the nickel or the manganese contents of these chromium-nickel alloys, all, of course, within certain limits, it having been recognized that the addition of the further amounts these elements decreased the rate of cold-work hardening. Thus, conventionally, an increase of the nickel content of the usual 18% chromium, 8% nickel by about 3%, giving an 18–11 chromium-nickel steel, results in a product displaying diminished work-hardening tendencies and thus improved cold-working properties. At the same time, however, the 18–11 chromium-nickel alloy does not display such cold-working properties as obviate the necessity for intermediate anneal; nor does it adequately decrease wear on the cold-forming dies.

An object of my invention, therefore, is to remove in substantial measure the several disadvantages heretofore confronting the art in the manufacture of cold-headed austenitic chromium-nickel stainless steel products, especially those of intricate head formation, all without necessity of intermediate anneal and while fully retaining the advantageous qualities of these steels, including illustratively, their nice surface appearance, their resistance to corrosion, their non-magnetic qualities and their capability of being worked to close dimensional tolerances.

Referring now to the practice of my invention, I find that by the addition of copper to the alloy, the rate of work-hardening is lowered much more drastically, rapidly and effectively than is true of nickel or manganese. Cold-headed articles formed of such steels are rapidly produced, in the substantial absence of intermediate anneal, and with markedly diminished die-wear.

I have not determined exactly by what phenomenon the addition of copper to the alloy brings about the beneficial results observed. For these results are at variance with what might be anticipated. Illustratively, the addition of copper to nickel hardens the metal and increases the rate of work-hardening. Perhaps the beneficial results achieved in the present instance are due to some stabilization lent the austenite. Or perhaps to some change in structure.

Irrespective of theory, however, I have found, by illustration, that increase in the copper content to appreciable extent is attended by marked increase in the degree of cold-working to which the metal can be subjected within practical working limitations without encountering objectionable work-hardening and without encountering a change from the non-magnetic condition to the magnetic condition. Another important factor is that while ordinarily the addition of copper to stainless steel is undesirable because of the red-shortening effect thereby produced, this does not appear to be particularly objectionable when employed in the amounts of my new steel and when correlated with particular amounts of chromium and nickel.

I have found that the broad range of the composition nicely suited for the formation of such cold-headed products is carbon up to 0.15%, manganese up to 15%, chromium 10% to 25%, nickel 7% to 20%, copper 1.0% to 6.0%, and remainder iron.

The manner in which additions of copper markedly reduce the work required to deform samples thereof is strikingly evident from consideration of the following table:

Table I

Heat No.	C	Cr	Ni	Cu	Cold Hardening Work Factor × 1,000 ft./lbs. per cu. in.
1	.063	17.70	6.56	------	152
2	.032	17.46	6.00	4.11	88
3	.067	17.43	8.06	------	133
4	.063	17.39	8.04	3.04	79
5	.075	17.02	10.15	------	109
6	.067	17.17	9.98	3.04	81
7	.060	17.83	9.98	4.91	76

ing in Heat 1. The cold-hardening work factor of Heat 2 has been lowered to a value only 58% of that of samples from Heat 1.

While Heats 1 and 2 are concerned with 18–6 chromium-nickel alloys, Heats 3 and 4 relate to 18–8 chromium-nickel alloys. As might be expected with increased nickel, the work factors of Heats 3 and 4 are lower, respectively, than those of Heats 1 and 2, respectively. Notably, however, the 3% copper present in Heat 4 results in 41% decrease in the cold-hardening factor.

As evident from Heats 5, 6, and 7, an increase of nickel to 18–10 chromium-nickel results in still further reduction of this work factor; while as to this alloy an addition of copper further reduces the work factor and an increase in the copper content results in a still further decrease of the work factor.

Of particular interest, it will be seen from a comparison of Heats 1, 5 and 6, for example, that while an increase of the nickel content from 6% to 10%, an increase of 4%, gives a lowering of the work factor from 152 down to 109, the addition of only 3% copper lowers the work factor from 152 down to 81. My steel, therefore, is seen to work-harden to a lesser extent. In addition, it is substantially cheaper than a steel in which decreased work-hardening is had at the expense of increased quantities of the costly and critical material nickel.

It is well recognized that the work-hardening of metals, including stainless steels, results in an increased tensile strength. Following severe cold-working, then, the ultimate tensile strength of the metal is ordinarily appreciably greater than before such cold-working was resorted to. Where the increase in the ultimate tensile strength is great, the cold-work is considered severe, where it is not particularly great the extent of the cold-work is not so severe. Advantage can be taken of the ultimate tensile figures to high-light the effect of the inclusion of copper on the severity of cold-work, as compared with the effect had with increase in the nickel content.

The comparative effects of copper and increased nickel on the severity of cold-work, as gauged by the increases in ultimate tensile strengths, are well illustrated in the following Table II, wherein I set forth the ultimate tensile strength of wire specimens after cold-drawing to various reductions. The advantageous effects attendant the addition of copper are seen from the lower strength values and the lower rate of increase in tensile values with cold-reduction.

Table II

Heat No.	C	Cr	Ni	Cu	Ultimate Tensile Str. after cold drawing				
					0%(Ann.)	20%×1,000 p. s. i.	40%×1,000 p. s. i.	60%×1,000 p. s. i.	75%×1,000 p. s. i.
8,949	.05	18.85	9.42	------	78	120	165	212	246
10,252	.05	18.17	11.42	------	82	117	152	187	212
58,075	.05	13.92	12.77	------	75	113	150	187	------------
64,007	.03	13.16	13.56	3.10	75	95	122	145	152

It will be noted, by reference to this table, that Heat 2 therein responds closely in analysis to Heat 1 with the exception that Heat 2 includes copper in the amount of 4.11%, an element lack-

While in an analysis range given at an earlier point in this disclosure, I have set forth a percentage range of the component metals which will give rise to marked increase in cold-working properties, I find that optimum results are achieved when the various component metals are present within the following more limited range, carbon .10% maximum, manganese .50 to 2.00%, chromium 10 to 20%, nickel 10 to 15%, copper 2.0 to 5.0%, remainder iron.

In the several embodiments, manganese can be employed at least partly in substitution for the nickel, while conversely, the nickel can be employed at least partly in substitution for the manganese. Additionally, it may be noted that the silicon content is maintained within the normal composition range. Similarly, phosphorus and sulfur are normally present in but small quantities, although they may be included in amounts up to 0.40% in cases where the cold-headed article is subjected to appreciable machining. Or, where desired, selenium in amounts up to 0.40% may be added. Columbium or titanium may be present in the usual amounts sufficient to stabilize the carbon, say about 8×% carbon minimum and 4×% carbon minimum, respectively. Molybdenum may be present in an amount as high as 4% to improve corrosion resistance. I find that none of these alloying elements significantly affects the rate of cold-work-hardening.

The precaution should be observed that the total quantity of chromium present in the metal should not be employed in excess of the maximum limit recited in the broad range of composition heretofore given, for I have found that with the high nickel level required for good finish effects, the inclusion of substantial amounts of chromium tends to increase the work-hardening effect of the alloy, a phenomenon perhaps attributable to solid-solution effects resulting in increased work-hardening as the total alloy content increases, i. e., as nickel and chromium contents increase. Thus, I seek to achieve a balance between the transformation-hardening effect and the solid-solution-hardening effect, the chromium and nickel contents being maintained within such limits that the copper will achieve maximum results in lowering the work-hardening rate.

It will be seen from the foregoing that the alloy, according to my practice, is readily adapted to the production of a variety of cold-headed or cold-upset articles. Moreover, it will be seen that these articles display marked advantages, as contrasted to those produced from the ordinary stainless steels, in that they are produced with a minimum number of cold-working operations; necessity for intermediate anneal is effectively avoided. Overall production time is drastically reduced, so that production costs are appreciably lowered. Intricate surface detail can be readily duplicated according to my new practice, while adhering nicely to close dimensional tolerances, and this in effective and predictable manner. Important savings attend upon the marked increase in life of the forming dies.

Illustratively, a variety of fasteners, of many different configurations, dimensions, and other individual characterizations, are readily formed from stainless steel stock, according to the practice of my invention. Bolts are readily produced, and the same is true of roll-threaded screws. My invention is especially suited for the production of the so-called, scrapless nuts, wherein metal rod is initially pierced to form a hole therein, which is subsequently expanded to required dimensions, the stock being thereupon tapped.

All these, as well as many other highly practical advantages attend upon the practice of my invention.

It is apparent from the foregoing that once the broad aspects of my invention are disclosed, many embodiments thereof will readily suggest themselves to those skilled in the art, accordingly, I intend the foregoing disclosure to be considered simply by way of illustration, and in no wise as a limitation.

I claim as my invention:

1. Stainless steel possessing cold-working and machining properties comprising up to 0.15% carbon, up to 15% manganese, from 10% to 25% chromium, from 7% to 20% nickel, from 1.0% to 6.0% copper, from incidental amounts up to 0.4% of the group sulfur, phosphorus and selenium, with remainder iron.

2. Stainless steel rod and wire possessing good cold-heading properties comprising up to 0.10% carbon, 0.50% to 2.00% manganese, 10% to 20% chromium, 10% to 15% nickel, 2.0% to 5.0% copper, from incidental amounts up to 0.4% of the group sulfur, phosphorus and selenium, and remainder iron.

3. Cold-upset austenitic stainless steel bolts, rolled-screws, scrapless nuts, snap-fasteners, and the like comprising up to 0.15% carbon, up to 15% manganese, from 10% to 25% chromium, from 7% to 20% nickel, from 1.0% to 6.0% copper, from incidental amounts up to 0.4% of the group sulfur, phosphorus and selenium, and remainder iron.

4. Non-magnetic cold-headed stainless steel bolts, rolled-screws, scrapless nuts, snap-fasteners and the like comprising up to 0.10% carbon, 0.50% to 2.00% manganese, 10% to 20% chromium, 10% to 15% nickel, 2.00% to 5.00% copper, from incidental amounts up to 0.4% of the group sulfur, phosphorus and selenium, and remainder iron.

5. Non-magnetic cold-headed austenitic stainless steel Phillips screws comprising up to 0.15% carbon, up to 15% manganese, from 10% to 25% chromium, from 7% to 20% nickel, from 1.0% to 6.0% copper, from incidental amounts up to 0.4% of the group sulfur, phosphorus and selenium, with remainder iron.

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