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COLD ROLLED MANGANESE STEELS

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There is a large and increasing demand for structural materials having very high strengths per unit of weight and per unit of volume, and great toughness and ductility. The principal demand has been by the makers of aircraft and other vehicles, but the advantages of high-strength, light-weight structures are gaining recognition in other fields.

Plastic-bonded non-metallic materials, aluminum-base alloys, and magnesium-base alloys are widely used to obtain a combination of great strength with light weight, but for many purposes the structures built of such materials are undesirably bulky, thus offsetting to a degree the advantage gained by a high ratio of strength to weight.

Austenitic-type chromium-nickel stainless steels, cold-rolled to a high tensile strength, have also gained considerable favor for the manufacture of airplanes, railway cars, and other structures. These steels are very tough and ductile, and offer the advantage not only of a high ratio of strength to weight but also of a high ratio of strength to volume. They are, moreover, very resistant to corrosion and ordinarily do not require surface-protection against the weather.

Several special alloy steels, containing but a few per cent of alloying ingredients, and submitted to strengthening heat treatments, have been used for a limited number of purposes, for instance, airplane tubing and railway trucks, wherein a high ratio of strength to weight is important; but such steels when welded and not specially annealed have not had enough toughness and ductility at very high strength levels to adapt them to all uses in the field of high-strength, light-weight structures.

An object of this invention is to provide a new material having a very high strength per unit of weight and per unit of volume, and great toughness and ductility.

Another object is to provide a new steel for use in cold drawing, cold rolling, and other cold forming operations.

Another object is to provide novel cold drawn, cold rolled, and otherwise cold formed steel articles; and a further object is to provide such steels and articles which are also resistant to progressive rusting.

In a search for steels which would achieve the objects of the invention, the so-called Hadfield manganese steels containing 10% to 14% manganese were investigated. The results were disappointing throughout the composition range, because the material cracked after relatively light cold rolling. Raising the manganese content to 16%, 17.5%, and 18% did not obviate this difficulty. When the manganese content rose to 20% or 30%, the material was difficult to hot roll.

I have discovered, however, that a manganese steel which is readily hot rolled, and is readily cold rolled or otherwise cold worked, and which has when sufficiently cold worked a very high strength and excellent ductility and toughness, can be obtained if the manganese content is maintained within certain narrow, critical limits, and if copper or both copper and nickel are added in certain small, critical proportions. I have also discovered that these steels have a substantial resistance to progressive rusting, which resistance can be considerably enhanced, without ill effect on the physical properties, by the addition of a small proportion of chromium.

The invention comprises steel articles of manufacture in the condition produced by cold drawing, cold rolling, or similar cold forming operations, containing manganese between 15.5% and 20%, preferably between 16% and 18%, between 0.25% and 4.5% nickel, preferably 1% to 2.5% nickel, and between 0.25% and 2.5% copper, preferably 0.5% to 1.75% copper, and preferably also containing chromium, remainder substantially iron. The resistance of these articles to progressive rusting is enhanced by the presence of chromium in a proportion between 0.25% and 7%, preferably 1% to 4%.

By "remainder iron" and "remainder substantially iron" as used herein and in the appended claims, I mean to include not only chemically pure iron but also iron containing the common impurities and incidental ingredients found in ordinary steels. For instance, carbon may be present in a proportion from 0.01% to 1% or somewhat higher without greatly altering the characteristics of the steel, although it is preferred that the carbon content be less than 0.35%. Nitrogen in a proportion up to about 0.15%, phosphorus up to about 0.2%, sulfur up to about 0.05%, silicon up to about 1%, and residual deoxidizers, scavengers, and grain refiners, such as calcium, may also be present.

The steels of the invention, described above, can be hot forged and hot rolled readily, without checking, cracking, or tearing, and can be cold worked, without intermediate or subsequent annealing at high temperatures, to obtain a very high strength while retaining great toughness and high ductility.

The strength and ductility of the steels of the invention are illustrated by the tensile test data in Table A, obtained on several typical steels within the composition limits described herein. The test data were obtained on standard coupon samples of cold-rolled strips, the amount of cold-rolling being indicated in the table. The coupon samples were each 0.035 inch thick, and were given no heat treatment during or following cold-rolling. The yield strengths at 0.2% offset were determined in accordance with the U. S. Navy Department specification No. 47S21.

Table A

Composition (remainder iron)						Tensile test data			
Percent Mn	Percent C	Percent Ni	Percent Cu	Percent Cr	Percent red.	E	Yield strength, p. s. i.	Tensile strength, p. s. i.	Percent el.
16.5	0.10	(1)	1.0	(1)	25	30	114,300	172,200	20
16.5	0.10	(1)	1.0	(1)	35	28	139,000	195,500	18
16.0	0.10	0.75	0.75	(1)	35	26	141,000	161,500	6
16.0	0.12	1.00	0.50	(1)	35	26	144,000	195,200	15
16.0	0.13	1.00	1.00	(1)	35		123,600	184,500	17
16.5	0.10	2.60	1.15	(1)	25	30	97,300	148,200	18
16.5	0.10	2.60	1.15	(1)	35	27	132,500	170,400	13
17.5	1.04	4.15	2.12	(1)	35	27	157,000	184,700	11
16.0	0.10	0.75	0.75	3.0	35	26	130,000	174,000	9
15.8	0.25	1.10	0.73	3.1	35	26.5	135,000	208,000	22
16.0	0.20	2.00	1.00	3.0	25	28	115,500	160,500	15
16.0	0.20	2.00	1.00	3.0	35	26	142,500	180,500	10
15.8	0.13	2.06	1.10	3.2	35	28	114,000	175,000	21

(1) None.

In the foregoing table, "per cent red." indicates the percentage reduction in thickness of section effected by cold rolling before testing; "E" indicates the initial tangent modulus of elasticity in millions of pounds per square inch; "yield strength p. s. i." represents the yield strength in tension, measured at 0.2% permanent set, in pounds per square inch; "tensile strength p. s. i." represents ultimate tensile strength in pounds per square inch; and "per cent el." represents percentage elongation of the tensile test specimen in rupture, in an initial gauge length of two inches.

Although the steels of the present invention are suitable for lightweight high strength members in the cold rolled condition, still further improvement in certain physical properties may be effected by subjecting the cold rolled steel to a low temperature heat treatment between 100 C. and 250° C. A suitable treatment is at 200° C. for 24 hours. At the lower end of the temperature range a somewhat longer time is required to effect the desired result, whereas the time may be lessened at the higher temperatures of the range. At the higher temperatures of the range, some benefit may be derived from heating for as short a period as 30 minutes. In other instances, particularly at the lower temperatures of the range, it may be desirable to heat for as long as 100 hours. Data illustrative of the marked improvement of the low temperature heat treatment on the stress-strain characteristics of the steels are given in Tables B and C.

Table B lists typical steels of the present invention and Table C comprises comparative physical data of the steels in both the as rolled and the as rolled and heat treated condition. Data are listed for physical tests in both tension and compression. The tabular headings correspond to those of Table A. Buckling stress in p. s. i. represents the load in pounds per square inch at which the test specimens buckled under compressive loading.

It will be noted from Table C that, the as rolled and heat treated specimens, marked "B" under the column headed "condition," show a higher yield strength in both tension and compression than corresponding specimens cold rolled but not heat treated, marked "A" in the same column. This effect is particularly pronounced in the specimens tested under compression. These specimens show an increase in yield strength of from 30,000 to 50,000 pounds per square inch over the untreated specimens.

The materials of this invention may be welded by the common welding methods, including the various "spot" electrical resistance welding methods, electric arc welding, and oxyacetylene torch welding. This characteristic is of particular value, because welding is usually faster and cheaper than riveting. The material need not be annealed after welding.

Table B

Steel No.	Composition (remainder iron)				
	Percent Mn	Percent Ni	Percent Cr	Percent Cu	Percent C
1	16.49	(1)	(1)	1.13	0.10
2	17.3	(1)	(1)	1.15	0.27
4	16.0	1.00	(1)	1.00	0.13
5	15.83	2.06	3.21	1.10	0.13
6	16.4	1.75	3.10	0.68	0.23

(1) None.

Table C

Steel No.	Percent red.	Condition	Tension				Compression		
			E	Yield strength, p. s. i.	Tensile strength, p. s. i.	Percent el.	E	Yield strength, p. s. i.	Buckling stress, p. s. i.
1	35	A	28	139,000	195,500	16	27	109,000	175,200
1	35	B	29.7	146,200	187,000	16	29	150,200	195,000
2	25	A	29	114,500	169,900	13	27	86,000	143,200
2	25	B	28	130,000	180,000	22			
2	35	A	28	148,500	198,200	3	28	112,000	178,300
2	35	B	30	158,800	214,000	11	29	160,500	205,200
4	35	A	27	123,600	184,500	17	25	109,000	172,500
4	35	B	28	140,000	181,800	17	27	143,300	185,600
5	35	A	27	114,000	175,000	21	26	87,600	150,000
5	35	B	26	130,000	170,500	19	27	119,500	156,400
6	35	A	27	135,000	187,800	22	28	90,300	160,200
6	35	B	28	144,300	185,000	18	28	145,500	173,000

A—As cold rolled.
B—As cold rolled plus 24 hours at 200° C. followed by air cooling.

I claim:

1. Steel article of manufacture in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising manganese between 15.5% and 20%, nickel between 0.25% and 4.5%, and copper between 0.25% and 2.5%, remainder substantially iron.

2. Steel article of manufacture in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising manganese between 16% and 18%, nickel between 1% and 2.5%, copper between 0.5% and 1.75%, remainder substantially iron.

3. Steel article of manufacture in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising approximately 16% manganese, 1.5% nickel, 0.75% copper, remainder iron.

4. Steel article of manufacture, resistant to progressive rusting, in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising manganese between 15.5% and 20%, nickel between 0.25% and 4.5%, copper between 0.25% and 2.5%, chromium between 0.25% and 7%, remainder substantially iron.

5. Steel article of manufacture, resistant to progressive rusting, in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising manganese between 16% and 18%, nickel between 1% and 2.5%, copper between 0.5% and 1.75%, chromium between 1% and 4%, remainder substantially iron.

6. Steel article of manufacture, resistant to progressive rusting, in the condition produced by cold drawing, cold rolling, or similar cold forming operations, comprising approximately 16% manganese, 1.5% nickel, 0.75% copper, 3% chromium, remainder iron.

7. A cold formed, high strength article composed of a steel containing manganese between 15.5% and 20%, nickel between 0.25% and 4.5%, copper between 0.25% and 2.5%, remainder substantially iron, said article being in the condition resulting from heating within the range of 100° C. to 250° C. for a time between 30 minutes and 100 hours.

8. A cold formed, high strength article composed of a steel containing manganese between 15.5% and 20%, nickel between 0.25% and 4.5%, copper between 0.25% and 2.5%, chromium between 0.25% and 7%, remainder substantially iron, said article being in the condition resulting from heating within the range of 100° C. to 250° C. for a a time between 30 minutes and 100 hours.

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