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CHROMIUM-CONTAINING STEELS

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This invention relates to chromium-containing steels, and more especially to chromium steels that are substantially non-hardenable.

One well known method of hardening iron depends, among other things, on a solution of carbon in the form of carbides in the iron, and the resulting product is known as steel. When chromium is added to iron containing carbon as carbide, the effect of carbon in producing hardness is even more pronounced. If chromium is present to the extent of about 12% in iron, the amount of carbon required to attain the eutectoid composition is only about 0.30%, thus showing that the presence of a given amount of carbon is more influential in producing hardness in these steels than in the plain carbon steels. This fact has been used to advantage in the production of stainless steels employed for cutlery purposes.

It is also well known that chromium imparts excellent corrosion resistance to steel, and the use of a steel containing chromium is advantageous in applications other than cutlery. In such other applications great hardness is detrimental in a large number of cases, and in order to obtain softer steels, the practice is to lower the carbon content. At the present time large tonnages of high chromium steels containing not more than 0.15% carbon, and in some cases 0.10% or less, are manufactured for use in resisting corrosion. Steels having even these low carbon contents still possess hardening ability, as shown by the fact that they must be annealed for at least several hours at the proper temperatures to impart softness or ductility, or both. However, the hardening ability of such steels depends greatly on their chromium content, because if this element is present to an extent greater than about 16% the metal cannot be appreciably hardened, although it is still necessary to anneal the wrought alloy to improve its ductility and to impart maximum softness.

We have found that if steels containing substantial amounts of chromium are treated with certain elements their hardening ability is greatly reduced, and may in many cases be substantially eliminated. An element that produces this result is columbium. The effect of this element when it is added to high chromium steels is indicated by the data given in Table I.

TABLE I

A. Metal in as-rolled condition

% Cr	% C	% Cb	Lb./sq. in.		% El. in 2"	% Red. of area	Erich. value	Brinell hardness
			Yield point	Max. stress				
5.44	0.10	-------	147,000	181,000	5	12	5	375
5.62	0.09	1.04	98,000	111,000	15	62	6	200
12.62	0.12	-------	149,000	204,000	3	8	5	387
12.42	0.10	1.18	39,200	63,300	30	54	7	131
18.29	0.08	-------	57,000	92,500	6	14	5	170
19.20	0.08	1.00	52,000	72,000	22	41	6.50	149
22.50	0.15	-------	61,000	94,500	7	11	5.50	170
22.85	0.12	1.47	53,000	75,000	19	39	6	131

B. Heated at 725–775° C. 4 hours and air cooled

12.62	0.12	-------	52,000	80,000	30	73	7.50	149
12.42	0.10	1.18	39,000	62,000	29	67	7.00	128

It is shown in section A of Table I that low carbon steels containing approximately 5, 12, 18 and 23% chromium in the as-rolled state possess very little ductility and those containing 5 and 12% chromium are also quite hard. The data given for a similar series of steels treated with columbium, show that in the same state these steels are ductile and soft. Section B of Table I shows the relative effects of annealing on a hardenable 12% chromium steel and on a 12% chromium steel treated with columbium; it is seen that the properties of the steel without columbium are greatly altered by annealing, while the properties of the columbium treated steel are not appreciably changed. It can also be noticed that the steel containing columbium is softer than the plain chromium steel, even in the annealed state.

The plain chromium steels containing in the neighborhood of about 12% chromium with low carbon are hardened appreciably by cooling them rapidly from temperatures in the neighborhood of 950° C. Our tests have shown that when such a steel is treated with a sufficient amount of columbium the metal is not appreciably hardened by cooling rapidly from these temperatures. The

data given in Table II show this advantage resulting from the addition of columbium to chromium steels.

TABLE II

Heated at 950–1000° C. 5 minutes and air cooled

% Cr	% C	% Cb	Lb./sq. in.		% El. in 2"	% Red. of area	Erich. value	Brinell hardness
			Yield point	Max. stress				
12.62	0.12	-------	117,000	149,000	4	6	3.50	302
12.42	0.10	1.18	37,000	62,000	37	73	9.30	116

While the data given above show that in the rolled state the columbium-bearing steels are soft and ductile, we believe it is advantageous to anneal the metal at least to relieve the strains produced by hot working. These results show that this can be done in a few minutes at these higher temperatures, whereas when the untreated steels are softened it is necessary to anneal them for several hours at lower temperatures.

It is realized that as the chromium content is gradually increased beyond 12% in low carbon steels the tendency to harden is lessened. When the chromium content reaches about 16% the steels cannot be greatly hardened, although they must be annealed to render them ductile. As the chromium rises further to 20% and upwards, this tendency to harden is further lessened, but it is again necessary to anneal to impart ductility. These steels are all rendered soft and ductile in the rolled state by the presence of columbium, and additions of this element can be beneficially made to metal containing as much as about 25%–30% chromium.

We do not depend on the effect of alloying columbium with the solid solution of chromium and iron to modify the physical characteristics of the alloy. Indeed it is found that if a considerable excess of columbium over that required to combine with the carbon is added, or if a relatively large amount of columbium carbide is present, the resulting steels are rendered somewhat less soft and ductile than those in which these excesses are avoided. Nevertheless, a substantial excess of columbium may in some cases be present without destroying the excellent ductility and softness of the metal and without otherwise modifying greatly the properties of the alloy. More specifically, the ratio of columbium to carbon should be at least about 8 to 1 in order to obtain maximum softness. The ratio of columbium to carbon may be increased without destroying the usefulness of this invention, but the amount of columbium in excess of that required to satisfy this 8 to 1 ratio should not exceed 2%, and preferably should not exceed about 1.5%, of the total alloy. In order to secure the very soft steels of the invention, the carbon content should not exceed about 0.5%, and preferably, in the case of steels containing up to about 16% chromium, the carbon content should not exceed about 0.2%; while in the steels containing approximately 16% to 30% chromium, the carbon should not exceed about 0.35%.

The data given in Table III illustrate the effects of various ratios of columbium to carbon on a representative chromium steel.

TABLE III

As-rolled

% Cr	% C	% Cb	Lb./sq. in.		% El. in 2"	% Red. of area	Erich. value	Brinell hardness
			Yield point	Max. stress				
13.62	0.11	-------	149,000	184,500	3	8	5	375
13.79	0.04	-------	127,000	152,000	6	13	5	170
12.65	0.14	0.58	177,500	206,300	1	7	5	418
13.62	0.15	1.09	86,000	125,200	7	11	6	228
12.42	0.10	1.18	39,200	63,300	30	54	7	131
13.54	0.06	1.07	43,000	62,000	22	38	6	131
12.58	0.10	2.58	47,000	81,500	14	29	6.50	159
12.63	0.11	3.58	52,500	86,400	22	39	5.6	170

Our researches have included the addition of other elements to high chromium steels; for example, such elements as uranium, molybdenum, and tungsten. The results have shown that when appreciable amounts of these elements are present the steels are still comparatively hard in the rolled state, showing that they do not produce the same result as columbium. This is shown in the data given below, in Table IV.

TABLE IV

% Cr	% C	% U	% W	% Mo	Lb./sq. in.		% El. in 2"	% Red. of area	Erich. value	Brinell hardness
					Yield point	Max. stress				
13.48	0.18	0.72	----------	----------	Tensile sample could not be obtained because metal was not machinable as rolled				4.00	430
13.62	0.07	----------	0.89	----------	118,000	144,000	4	6	6.00	269
13.57	0.05	----------	2.57	----------	73,000	101,500	3	7	6.00	196
12.78	0.14	----------	----------	1.64	None shown	148,000	None shown		4.80	418
13.62	0.10	----------	----------	----------	149,000	184,500	3	8	5.00	375
13.79	0.04	----------	----------	----------	127,500	152,500	6	13	5.00	170

We have further found that if the carbon present in these chromium steels is combined with columbium, their resistance to oxidizing media is enhanced. This is shown by the fact that low carbon steels containing less than about 12% chromium exhibit greater resistance to nitric acid when they are treated with this element. Thus, it will be noted that treating these steels with columbium apparently leaves practically all of the chromium present in solid solution to impart inherently more corrosion resistance.

Columbium produced from the common ores of this element is usually associated to some extent with tantalum. Traces of tantalum will therefore usually be present as an impurity in the steels of the invention, but it is found that traces of this impurity do not modify markedly the properties of the alloys.

There will be instances in which it is desirable to leave a part of the carbon in combination with the iron and chromium. For example, optimum softness may not be desired under all conditions, and a high chromium steel containing 0.20% to 0.50% carbon may serve admirably if say ap-

proximately one-half of the carbon is combined with columbium, that is, if the ratio of columbium to carbon is say about 4 to 1. In such a case the steel would have equivalent softness to an untreated steel containing about 0.10% to 0.25% carbon. Such a procedure may also prove to be economical in remelting high chromium steel scrap, during which operation there is a marked tendency to pick up carbon.

It will usually be desirable not to exceed about 1% manganese, 1% silicon, or a total of about 1% of other metals and metalloids in the alloys of the invention, where highly soft and ductile alloys are to be obtained.

We claim:

1. Alloys comprising iron, chromium, columbium and carbon, the chromium content being between about 2% and about 30%, the carbon content being not more than about 0.50%, and the columbium content being at least about four times the carbon content and not more than about eight times the carbon content plus 2% of the total alloy; the balance being substantially iron.

2. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 2% and about 30%, the carbon content being not more than about 0.5%, and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 2% of the total alloy; the balance being substantially iron.

3. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 2% and about 30%, the carbon content being not more than about 0.5%, and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 1.5% of the total alloy; the balance being substantially iron.

4. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 2% and about 16%, the carbon content being not more than about 0.2%, and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 1.5% of the total alloy; the balance being substantially iron.

5. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 16% and about 30%, the carbon content being not more than about 0.35%, and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 1.5% of the total alloy; the balance being substantially iron.

6. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 4% and about 8%, the carbon content being not more than about 0.5% and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 1.5% of the total alloy; the balance being substantially iron.

7. Alloys containing iron, chromium, columbium and carbon, the chromium content being between about 2% and about 30%, the carbon content being not more than about 0.5%, and the columbium content being at least about eight times the carbon content and not more than about eight times the carbon content plus 2% of the total alloy; not more than about 1% manganese, not more than 1% silicon, and not more than about 1% of incidental impurities; the balance of the alloy being iron.

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