June 30, 1936. F. M. BECKET ET AL 2,046,012

HEAT TREATMENT OF CHROMIUM ALLOY STEELS

Original Filed April 9, 1934

Fig 1

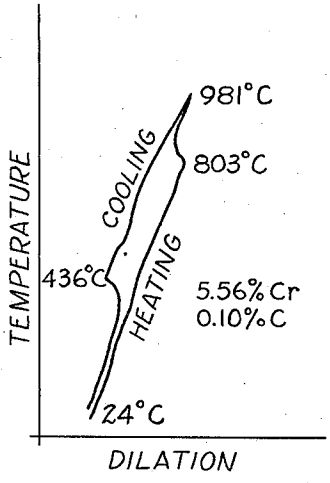


Fig 2

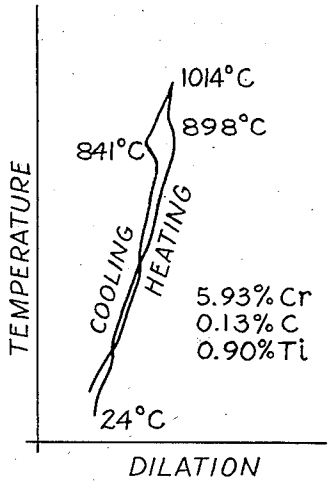


Fig 3

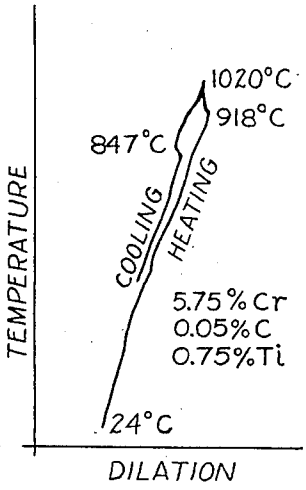


Fig 4

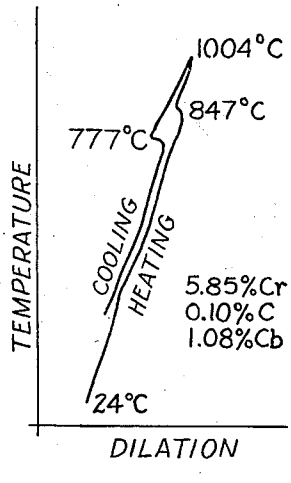


Fig 5

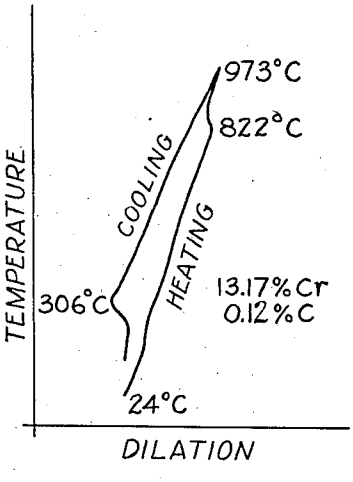
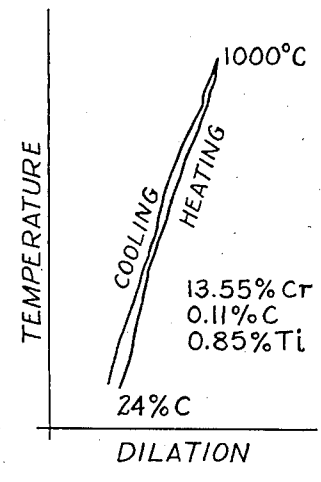


Fig 6



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Patented June 30, 1936 2,046,012

UNITED STATES PATENT OFFICE

2,046,012

HEAT TREATMENT OF CHROMIUM ALLOY STEELS

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Original application April 9, 1934, Serial No. 719,756. Divided and this application May 8, 1935, Serial No. 20,332

4 Claims. (Cl. 148—21.5)

The invention relates to a process of heat treating certain chromium-containing steels, by heating and cooling them, either slowly or rapidly, from temperatures above or below those at which the thermal changes ordinarily occur in the ferritic types of chromium-bearing steels. This application is a division of our application Serial No. 719,756 filed April 9, 1934.

When chromium is added to a steel the critical temperature range of the steel is raised appreciably, and the product can be fully softened only by heating for comparatively long periods at temperatures slightly below the critical range, followed by slow cooling. For example, a hot-worked steel, containing about 0.12% carbon and 12% chromium cannot be fully softened unless it is held for a period of several hours at temperatures not greater than about 800° C. After holding such steel at this temperature for a sufficient period of time it is necessary to cool it slowly in order to attain the softness desired. Such a procedure is carried out to prevent the metal from air hardening. The extent to which a given steel air hardens depends on its chromium and carbon contents.

If substantially all of the carbon present in the chromium-bearing metal is in combination with elements such as titanium and columbium, instead of chromium or iron, or both, the steel can be rendered soft and ductile by holding it for a period of only a few minutes, instead of hours, at temperatures within a range from somewhat below to somewhat above the normal critical range of chromium steels. Also, these steels can be cooled from these temperatures either rapidly or slowly without greatly impairing their properties. The economic advantage of such a process for annealing chromium steels is apparent.

An object of the invention is to provide a method of heat treating chromium steels wherein substantially all of the carbon present is in combination with titanium or columbium.

The results of a few tests conducted on sheet steels of twenty gage containing up to about 14% chromium with and without titanium are given in Table No. I.

Table No. I

% Cr	% C	% Ti	Condition of steel	Erichsen value	Rockwell "B" values
5.76	0.12	------	As rolled	4.80	113
5.76	0.12	------	Heated at 650° C. 4 hrs. and air cooled.	6.50	98
5.76	0.12	------	Heated at 750° C. 10 min. and air cooled.	7.60	100
5.76	0.12	------	Heated at 750° C. 4 hrs. and air cooled.	8.00	85
5.76	0.12	------	Heated at 900° C. 10 min. and air cooled.	4.90	110
5.93	0.13	0.90	As rolled	8.20	86
5.93	0.13	0.90	Heated at 650° C. 4 hrs. and air cooled.	8.10	79
5.93	0.13	0.90	Heated at 750° C. 10 min. and air cooled.	8.80	76
5.93	0.13	0.90	Heated at 750° C. 4 hrs. and air cooled.	9.90	63
5.93	0.13	0.90	Heated at 900° C. 10 min. and air cooled.	9.20	70
13.60	0.13	------	As rolled	5.00	113
13.60	0.13	------	Heated at 650° C. 4 hrs. and air cooled.	6.50	98
13.60	0.13	------	Heated at 650° C. 12 hrs. and furnace cooled.	7.00	89
13.60	0.13	------	Heated at 750° C. 10 min. and air cooled.	7.50	96
13.60	0.13	------	Heated at 750° C. 4 hrs. and air cooled.	8.40	76
13.60	0.13	------	Heated at 900° C. 10 min. and air cooled.	4.80	112
13.60	0.13	------	Heated at 1000° C. 5 min. and air cooled.	5.00	100
13.35	0.11	0.85	As rolled	8.10	88
13.35	0.11	0.85	Heated at 650° C. 4 hrs. and air cooled.	8.20	82
13.35	0.11	0.85	Heated at 650° C. 12 hrs. and furnace cooled.	8.65	81
13.35	0.11	0.85	Heated at 750° C. 10 min. and air cooled.	8.00	80
13.35	0.11	0.85	Heated at 750° C. 4 hrs. and air cooled.	9.00	70
13.35	0.11	0.85	Heated at 900° C. 10 min. and air cooled.	9.30	70
13.35	0.11	0.85	Heated at 1000° C. 5 min. and air cooled.	9.40	68

Table I shows clearly that the titanium-containing steels can be softened by heating for either long or short periods at temperatures be-

low and above those at which the critical changes occur in the titanium-free steels. Similar results are obtained when suitable amounts of columbium are substituted for the titanium.

Low carbon steels containing over about 16% chromium are considerably less hardenable than the lower chromium steels. Nevertheless, these high chromium steels are fairly brittle in the rolled state and cannot be rendered sufficiently ductile and soft unless they are held for comparatively longer periods at the proper temperatures. As indicated in Table II, the addition of the proper amount of titanium to these steels renders them capable of being made soft and ductile by heating for only a few minutes at temperatures up to about 1000° C.

Table No. II

% Cr	% C	% Ti	Condition of steel	Erichsen value	Rockwell "B" value
18.29	0.06	------	As rolled	5.25	86
18.29	0.06	------	Heated at 750° C. 4 hr. and air cooled.	7.00	76
18.29	0.06	------	Heated at 900° C. 10 min. and air cooled.	6.50	83
18.29	0.06	------	Heated at 1000° C. 5 min. and air cooled.	2.70	83
18.00	0.13	0.78	As rolled	7.00	72
18.00	0.13	0.78	Heated at 750° C. 4 hr. and air cooled.	7.00	74
18.00	0.13	0.78	Heated at 900° C. 10 min. and air cooled.	9.00	66
18.00	0.13	0.78	Heated at 1000° C. 5 min. and air cooled.	9.00	69

Similar results are obtainable by the use of columbium instead of the titanium.

The effects of titanium and columbium on chromium steels is further elucidated by dilatometric tests. Dilation curves obtained in tests on chromium steels with and without additions of titanium and columbium are shown in the accompanying drawing, in which

Figure 1 is a dilation curve obtained on a steel containing 5.56% chromium, 0.10% carbon, remainder substantially all iron.

Figure 2 is a dilation curve of a steel containing 5.93% chromium, 0.13% carbon, 0.90% titanium, remainder substantially all iron.

Figure 3 is a dilation curve of a steel containing 5.75% chromium, 0.05% carbon, 0.75% titanium, remainder substantially all iron,

Figure 4 is a dilation curve of a steel containing 5.85% chromium, 0.10% carbon, and 1.08% columbium, remainder substantially all iron,

Figure 5 is a dilation curve of a steel containing 13.17% chromium, 0.12% carbon, remainder substantially all iron,

Figure 6 is a dilation curve of a steel containing 13.55% chromium, 0.11% carbon, 0.85 %titanium, remainder substantially all iron.

Referring to Figures 1, 2, 3, and 4, it is seen that an effect of the titanium or the columbium on steels of the 5% chromium type is to raise considerably the AC–1 point, and to raise the AR–1 point even more, the latter being brought nearly to the temperature of the AC–1 point.

It may be seen from Figures 5 and 6 that the addition of titanium to the 13% chromium type practically eliminates the critical changes that normally occur on heating and cooling the titanium-free chromium steels between room temperature and 1000° C.

It is unnecessary in the present invention to maintain a maximum of 0.10% carbon in order to insure maximum softness and workability, because if suitable amounts of titanium are present equally soft steels may be obtained with somewhat higher carbon. This is clearly demonstrated by Table III, in which are given the hardness and Erichsen values of 13% chromium steels, low and high in carbon, in the as-rolled state and when heat treated by heating at 1000° C. for five minutes and then air cooled.

Table No. III

% Cr	% C	% Ti	Condition of steel	Erichsen value	Rockwell "B" hardness
13.35	0.11	0.85	As rolled	8.1	88
13.35	0.11	0.85	Heat treated	9.4	68
13.32	0.34	1.76	As rolled	6.3	76
13.32	0.34	1.76	Heat treated	8.6	69
13.32	0.58	2.13	As rolled	6.0	88
13.32	0.58	2.13	Heat treated	7.7	80

The method of the invention can be applied to metal containing between 4% and 30% chromium, a suitable proportion of titanium or columbium, not over 0.50% (preferably not over 0.25%) carbon, and the remainder chiefly iron. Such metals will also contain the usual amounts of manganese and silicon that are employed for deoxidizing purposes. To attain substantially its full effect in facilitating the softening heat-treatment, the percentage of titanium present in the steel should be at least three times (and preferably four to six times) the percentage of carbon. When columbium is used, its percentage should be at least six times (and preferably eight to ten times) the carbon percentage. Larger proportions of the softening metal may be used but we prefer that the percentage of titanium or columbium in the steel shall not exceed its respective stated preferred minimum value by more than 1.5%.

We claim:

1. Method of heating treating ferritic steels containing about 4% to 30% chromium; carbon in an amount not over about 0.50%; columbium, the columbium content being at least about eight times the carbon content and being not more than eight times the carbon content plus about 1.5%; the remainder principally iron; which comprises heating the steel to a temperature between about 700° C. and about 1000° C., holding it at said temperature for a time not over about two hours, and then cooling it to room temperature.

2. Method of heat treating ferritic steels containing about 4% to 30% chromium; carbon in an amount not over about 0.25%; columbium, the columbium content being at least about eight times the carbon content and being not more than eight times the carbon content plus about 1.5%; the remainder principally iron; which comprises heating the steel to a temperature between about 800° C. and about 900° C., holding it at said temperature for a time not over about an hour, and then rapidly cooling it to room temperature.

3. Method of heat treating ferritic steels containing about 4% to 30% chromium; carbon in an amount not over about 0.25%; columbium, the

columbium content being at least about eight times the carbon content and being not more than eight times the carbon content plus about 1.5%; the remainder principally iron; which comprises heating the steel to a temperature between about 800° C. and about 900° C., holding it at said temperature for a time not over about an hour, and then air cooling it to room temperature.

4. As an article of manufacture, the product of the process defined in claim 1.

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