Patented Dec. 6, 1938

2,139,538

UNITED STATES PATENT OFFICE

2,139,538

CHROMIUM ALLOY STEEL TUBE

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No Drawing. Application May 24, 1934, Serial No. 727,280

4 Claims. (Cl. 148—12)

The invention relates to chromium alloy steel seamless tubes, and to similar articles, fabricated by hot or cold forming. This application is a continuation in part of our application Serial No. 640,778, filed May 24, 1934.

Chromium steel seamless tubes have been widely used commercially to resist corrosion and oxidation at high temperatures. While it has been possible to fabricate seamless tubes from chromium steels, difficulties have been encountered, because of certain inherent properties of the chromium steels customarily used.

When chromium is added to steel the hardening effect of any carbon present is greatly intensified. This is especially true of steels containing about 3% to 16% chromium, which are known as air-hardening steels. In fabricating articles such as seamless tubes from these air-hardening steels, care must be exercised to prevent cracking of the metal during cooling. Further, the addition of about 3% to 16% chromium to steels renders sluggish the thermal changes which occur during heating and cooling, and it is necessary to use long heat treating periods, followed by slow cooling, in order to soften the metal.

If the chromium content of the steels exceeds about 16%, the tendency of steel to air-harden is considerably less than that of the steels lower in chromium, and when the amount of chromium is about 25% or more there is practically no tendency for the steel to harden on cooling from elevated temperatures, provided the carbon percentage is reasonably low. However, the steels containing more than about 16% chromium possess little ductility in the as-rolled condition, and to improve their ductility they must be heated for relatively long periods at the proper annealing temperatures. Steels containing more than about 20% chromium must be rapidly cooled from the annealing temperatures to avoid brittleness. In some instances, the long heat treatment required after hot rolling causes the development of very large grains which weaken the article. As a rule, the large grains occur only in certain parts of a given article, and as might be expected these parts are deficient in ductility.

We have discovered that the air-hardening tendencies of steels containing from about 3% to about 16% chromium can be strongly inhibited if the steel contains suitable additions of titanium or columbium, or both.

We have also discovered that steels containing about 16% to about 30% chromium are rendered softer and more ductile in the as-rolled state if the steel contains suitable additions of titanium or columbium, or both.

We have also found that seamless tubes and similar articles formed by hot-working, suitably at temperatures initially above about 1000° C. but below the melting point of the metal, and containing about 3% to 30% chromium; carbon in amounts not over 0.5% at the most, and preferably not over 0.2% in the steels containing about 3% to 16% chromium or 0.3% in steels containing about 16% to 30% chromium; and suitable amounts of titanium or columbium, or both; the remainder chiefly iron; are soft and ductile in the hot-worked condition, instead of hard and relatively brittle.

Moreover, the tubes of the invention may readily be fully softened by heating them for a relatively short period at a temperature in excess of about 750° C. It is not necessary to keep these tubes at the annealing temperature for longer than two hours to secure sufficient softness, provided a sufficiently high temperature is used. Further, all these steels may be cooled either rapidly or slowly from elevated temperatures without producing either hardness or brittleness. Rapid cooling, that is, air-cooling or quenching as opposed to furnace-cooling, from the elevated temperatures used in hot-forming or annealing, does not produce marked hardening even in tubes containing the lower percentages of chromium.

In the following table are given data obtained from certain tests of chromium alloy seamless tubes. In this table are indicated the chemical analyses of the tubing, the balance in each case being substantially all iron; the heat treatment of the tubes A representing "as hot formed", B representing "heated at 750° C. 4 hours and air-cooled" (a suitable annealing treatment for straight chromium steels), and C representing "heated at 900° C. 10 minutes and air-cooled"; the Brinell hardness; and the results of tests in which the tubing was crushed in a press. All

tubes tested had an outside diameter of 2.375 inches and a 0.25 inch wall.

Composition				Heat treatment	Brinell hardness	Results of crushing tests
Per-cent Cr	Per-cent C	Per-cent Ti	Per-cent Mo			
5.50	0.10	------	------	A	375	Cracked without bending.
5.50	0.10	------	------	B	131	Crushed flat without cracking.
5.50	0.10	------	------	C	340	Cracked after slight crushing.
6.09	0.11	0.90	------	A	141	Crushed flat without cracking.
6.09	0.11	0.90	------	B	140	Do.
6.09	0.11	0.90	------	C	118	Do.
5.90	0.14	0.73	0.56	A	149	Crushed flat without cracking.
5.90	0.14	0.73	0.56	B	141	Do.
5.90	0.14	0.73	0.56	C	120	Do.

These data show, first, that the ordinary 6% chromium steel tubes are relatively brittle and hard in the rolled state, and that a long annealing period is required to soften the metal and render it satisfactorily ductile; second, that 6% chromium steel tubes containing moderate amounts of titanium are soft and ductile in the as-rolled state, and that they are fully softened by annealing for only a few minutes at temperatures in the vicinity of 900° C.; and, third, that 6% chromium steel tubes containing moderate amounts of both titanium and molybdenum have substantially the same ductility and softness as those containing the titanium alone.

Similar results have been obtained in the case of chromium steels with other chromium, titanium, and carbon contents, and with steels containing columbium instead of titanium.

In order to obtain the full benefits of this invention the content of titanium or columbium, or both, must be strictly controlled. If titanium alone is used, the content of this material should be at least twice the carbon content, but not more than four times the carbon content plus an excess of 1.00% of the steel, preferably the excess is not over about 0.5% of the steel. Columbium may be substituted for the titanium in the ratio of two parts by weight of columbium for one of titanium; but preferably the maximum content of columbium does not exceed about 5%.

Molybdenum in amounts up to about 2% or tungsten in amounts up to about 3% may be included in the tubes of the invention to advantage. Small amounts of metals and metalloids usually present in commercial steels as impurities, deoxidizers, scavengers, and so forth, for example, manganese, silicon, aluminum, zirconium, sulfur, and phosphorus, may also be present in the steel of the tubes without departing from the invention.

Particularly useful for oil-cracking tubes and similar articles for use at elevated temperatures are those tubes of the present invention which contain about 4% to about 10% chromium, less than 0.2% carbon, and preferably up to about 1% molybdenum.

The tubes of the invention are not only easier and cheaper to fabricate than the chromium steel tubes heretofore known, but they are also more ductile, strong and uniform, and they may be straightened or bent, hot or cold, to a great extent without danger of breakage, behaving in this respect somewhat like carbon steel tubes.

This application contains subject-matter in common with our joint applications Serial Numbers 640,778 and 640,900, both filed on November 2, 1933. Our application Serial No. 640,900 issued as Patent No. 1,954,344 on April 10, 1934.

We claim:

1. Chromium alloy ferritic steel seamless tube characterized by extreme ductility and a Brinell hardness number between about 100 and 200, and having substantially the composition: 3% to 30% chromium, a carbon content not over about 0.3%, titanium at least twice the carbon content but not exceeding four times the carbon content by more than 1% of the steel, part of the titanium being replaceable by columbium, the remainder being chiefly iron; which tube has been formed at temperatures initially above 1000° C. but below the melting point thereof, rapidly cooled from the forming temperature, and subsequently annealed for a time from a few minutes to not over two hours at a temperature above 750° C. and then rapidly cooled.

2. Chromium alloy ferritic steel seamless tube characterized by extreme ductility and a Brinell hardness number between about 100 and 170, and having substantially the composition: 3% to 16% chromium, a carbon content not over about 0.2%, titanium at least twice the carbon content but not exceeding four times the carbon content by more than 0.5% of the steel, and the remainder chiefly iron; which tube has been formed at temperatures initially above 1100° C. but below the melting point thereof, rapidly cooled from the forming temperature, and subsequently annealed for a time from a few minutes to not over one hour at a temperature between 850° and 950° C. and then rapidly cooled.

3. Method of making soft and ductile chromium alloy ferritic steel hot-wrought articles having a Brinell hardness number between 100 and 200 which comprises hot-forming, at temperatures initially between 1000° C. and the melting point, an alloy steel having substantially the composition: 3% to 30% chromium, carbon in an amount not over 0.3%, titanium in an amount at least twice the carbon content but not exceeding four times the carbon content by more than 1% of the steel, part of the titanium being replaceable by columbium, and the remainder principally iron; rapidly cooling the article from the forming temperature; subsequently annealing the article for a time from a few minutes to not over two hours at a temperature above 750° C.; and then rapidly cooling the article from the annealing temperature.

4. Method of making soft and ductile chromium alloy ferritic steel seamless tubes having a Brinell hardness number between 100 and 170 which comprises hot-forming into a seamless tube, at a temperature initially between 1000° C. and the melting point, an alloy steel having substantially the composition: 3% to 16% chromium, carbon in an amount not over 0.2%, ti-

tanium in an amount at least twice the carbon content but not exceeding four times the carbon content by more than 1% of the steel, and the remainder principally iron; rapidly cooling the article from the forming temperature; subsequently annealing the article for a time from a few minutes to not over one hour at a temperature between 850° C. and 950° C.; and then rapidly cooling the article from the annealing temperature.

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