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WELDED JOINT AND METHOD OF MAKING THE SAME

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The invention is a method of welding and a welded joint having new and useful properties.

Steels which contain about 2% to about 16% chromium, appreciable amounts of carbon up to about 0.5%, and in which the iron is in the ferritic condition, harden when quenched or air cooled from elevated temperatures; but this property may be substantially eliminated by adding to the steels at least about eight times, but not over thirty times, as much columbium as carbon. Ferritic steels which contain about 16% to about 30% chromium and up to about 0.5% carbon are relatively hard in all conditions of heat treatment, are rather brittle when slowly cooled from elevated temperatures, and can be fully annealed only by holding at elevated temperatures for several hours and by subsequent rapid cooling. These higher chromium steels may be made softer and capable of more rapid annealing by the addition of at least about eight times, but not over thirty times, as much columbium as carbon.

The above described chromium-columbium steels, when heated at elevated temperatures such as are encountered, for example, during welding, lose an appreciable proportion of the ductility and toughness characteristic of the mechanically worked steels of the same composition. This phenomenon is apparently connected with the increase in grain size at high temperatures, but many of the known expedients for decreasing the average grain size of steels fail to improve the ductility and toughness of the chromium-columbium steels at elevated temperatures. For example, the addition of about 1% of nickel or copper greatly refines the grain size of the chromium-columbium steels, but destroys their softness and ductility.

The present invention is based on the discovery that suitable additions of tungsten or molybdenum, or both, greatly refine the grain structure of these columbium bearing steels withoutly greatly increasing their hardness or destroying their toughness. At least about 0.5% tungsten is required to secure substantial benefits, and more than about 2.5% of this element destroys the toughness of the steel. The preferred tungsten content is between about 1% and about 1.5%. If molybdenum is substituted for tungsten it should not exceed 2%.

The necessity for limiting the amount of tungsten or molybdenum in these steels is demonstrated by the following data in Table A which indicate the impact strengths of several steels in the rolled and heat-treated (fully softened) condition:

Table A

Analysis				Izod impact strength ft. lbs.	Brinell hardness number
% Cr	% C	% Cb	% W		
5.62	0.09	1.04	None	105	143
6.43	0.06	1.29	0.67	92	156
6.40	0.10	1.07	1.18	103	143
6.68	0.06	1.19	1.98	36	156
6.56	0.06	1.19	3.42	3	159

The beneficial effects of suitable additions of tungsten upon the welding characteristics may conveniently be illustrated by the data in Table B. These data were obtained by welding the edges of steel plates ⅛ inch thick, grinding off excess filler metal above the surfaces of the plates, cutting a coupon about 8 inches long and 2 inches wide, the welded joint being about in the center of the coupon and transverse to the longer axis of the coupon, holding one end of the coupon in a heavy vise, bending the coupon with hammer blows applied at the free end of the coupon until the weld just began to crack, and then measuring the approximate angle of bend. In Table B, the angles of bend are given under the heading "Bend test"; under "A" appear the angles obtained on samples as welded, with no further heat treatment, while under "B" are the angles obtained on samples which, after welding, were heated for 1 to 3 minutes at about 900° C. (with the welding torch) and then air-cooled.

Table B

Rod analysis				Plate analysis			Bend tests	
% Cr	% C	% Cb	% W	% Cr	% C	% Ti	A	B
6.34	0.07	1.55	Nil	5.93	0.12	0.90	90°	160°
6.52	0.06	1.65	1.55	5.95	0.12	0.80	160°	*180°
13.19	0.07	2.17	Nil	13.35	0.11	0.85	85°	150°
13.24	0.09	1.66	1.01	13.35	0.11	0.85	180°	*180°
25.40	0.10	2.11	Nil	25.60	0.12	0.70	50°	90°
24.80	0.09	1.94	0.88	25.60	0.12	0.70	70°	120°

*Weld did not crack after 180° bend.

The invention may be applied to steels containing from about 2% to about 30% chromium and up to about 0.5% carbon; but it is of particularly great value when applied to steels containing about 4% to about 20% chromium and up to about 0.30% carbon. The metal of the articles to be welded preferably contains sufficient titanium to decrease substantially the hardness and hardenability of the steel (a ratio of titanium to carbon upwards of about four, but not more than about 1% excess titanium over this ratio of four); but this feature is not essential. The weld filler material should have a columbium content at least eight times as great as the carbon content but not more than ten times the carbon content plus 1.5%. Preferably, the excess of columbium over ten times the carbon does not exceed about 0.75%.

I claim:

1. A strong and ductile welded joint comprising adjacent edges of at least two body portions and weld filler material between and uniting said adjacent edges, said body portions and filler material being composed of ferritic steel containing 2% to 30% chromium and up to 0.5% carbon, and said filler material containing substantially no unstable carbides which can be dissolved and reprecipitated in said material and containing columbium in an amount at least about eight times, and not over about 1.5% plus ten times, the carbon content of said material, and about 0.5% to 2.5% of at least one metal of the group consisting of molybdenum and tungsten, remainder iron.

2. A strong and ductile welded joint comprising adjacent edges of at least two body portions and weld filler material between and uniting said adjacent edges, said body portions and filler material being composed of ferritic steel containing 4% to 20% chromium and up to 0.3% carbon, and said filler material containing substantially no unstable carbides which can be dissolved and reprecipitated in said material and containing columbium in an amount at least about eight times, and not over about 0.75% plus ten times, the carbon content of said material, and about 0.5% to 1.5% of at least one metal of the group consisting of molybdenum and tungsten, remainder iron.

3. A method of uniting adjacent edges of ferritic chromium steel articles containing about 2% to 30% chromium and up to about 0.5% carbon, by depositing between said edges molten weld filler metal composed of ferritic steel containing about 2% to 30% chromium and up to about 0.5% carbon, remainder iron, which method comprises introducing into said molten weld filler material about 0.5% to 2.5% of at least one metal of the group consisting of tungsten and molybdenum, and columbium in an amount at least about eight times, and not over 1.5% plus ten times, the carbon content of said weld filler material; said columbium being effective to prevent the existence in said filler material of any substantial amount of unstable carbides which could be dissolved and reprecipitated in said material.

4. A method of uniting adjacent edges of ferritic chromium steel articles containing about 4% to 20% chromium and up to about 0.3% carbon, by depositing between said edges molten weld filler metal composed of ferritic steel containing about 4% to 20% chromium and up to about 0.3% carbon, remainder iron, which method comprises introducing into said molten weld filler material about 0.5% to 1.5% of at least one metal of the group consisting of tungsten and molybdenum, and columbium in an amount at least about eight times, and not over 0.75% plus ten times, the carbon content of said weld filler material; said columbium being effective to prevent the existence in said filler material of any substantial amount of unstable carbides which could be dissolved and reprecipitated in said material.

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