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HEAT-RESISTING ALLOYS

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This invention relates to ferrous alloys and particularly to such alloys capable of being effectively employed at elevated temperatures such, for example, as the temperatures encountered in the cylinders and exhaust passages of internal combustion engines or in the working passages of gas turbines.

Ferrous alloys containing relatively large amounts of chromium and nickel and also containing varying but smaller percentages of either tungsten, molybdenum and columbium have been known for some time and have been used in applications requiring strength at temperatures such as above suggested, i. e., at temperatures within the range of 1000° F.-1600° F. These presently known alloys, however, have one or all of the following drawbacks, to wit: lack of requisite strength at high temperatures; lack of structural stability, i. e., they may fail suddenly with a brittle fracture; and they cannot be fabricated under ordinary commercial practices.

On the other hand, chromium and nickel additions to ferrous alloys increase resistance to scaling and corrosion at high temperatures, and an object of my invention is to produce a ferrous alloy containing chromium and nickel and which is characterized by its strength at elevated temperatures.

A further object is to produce a heat-resistant ferrous alloy which has structural stability even when subjected to temperatures within the range of 1000° F.-1600° F. and which is characterized by its strength at such temperatures.

A further object is to produce a heat-resistant ferrous alloy having structural stability and which is easily fabricated by forging, rolling and/or machining.

These and other objects are attained by means of a ferrous alloy containing both chromium and nickel in substantial amounts and also containing simultaneous additions of tungsten, molybdenum and columbium in substantially balanced ratio.

For the purpose of more specifically defining my invention, I note that the alloy embodying it includes the elements below set forth within the ranges set forth:

	Per cent
Carbon	0.20-0.60
Chromium	12.00-22.00
Nickel	10.00-30.00
Molybdenum	2.00-8.00
Tungsten	2.00-6.00
Columbium	2.00-6.00

with the remainder iron and the usual contaminating substances in common amounts.

In connection with the alloy above defined, it should be noted that it is quite difficult to separate columbium and tantalum and that, therefore, some small amount of tantalum may be and probably will be present in the alloy. Commercial ferro-columbium is ordinarily designated as containing approximately 65% columbium and up to 5% tantalum, with the result that something more than a trace of tantalum is ordinarily present in an alloy containing about 4% of columbium. For this reason tantalum must be included as a contaminating substance in connection with the above defined alloy.

In the process of proving my invention I have made several hundred induction melts and have forged, rolled and tested the products of these melts under conditions such as to determine their heat-resisting characteristics and their strength at temperatures approximating 1500° F. All alloys including the alloying constituents above defined, within the ranges set forth, proved superior in strength at high temperature to prior known alloys. They were also characterized by structural stability and were more readily fabricated, under ordinary mill practices, than known alloys, or than new alloys including the elements named but in which the percentages of molybdenum, tungsten and columbium were outside the range of percentages above set forth or were not present in a balanced ratio.

The significant and highly important feature of my invention is that the alloy embodying it not only contains all three of the elements molybdenum, tungsten and columbium, but also contains those elements in a substantially balanced ratio.

In the following table I have set forth a number of alloys, but primarily for the purpose of disclosing the significance and the importance of the balanced ratio as to the constituents, molybdenum, tungsten and columbium. This table discloses that the highest value for strength under heat is obtained with melt S495, although the table also discloses that variations in the content of either of the constituents, molybdenum, tungsten or columbium; within the ranges first above set forth, produce a highly desirable alloy from the standpoint of strength at elevated temperature, provided each of the other two constituents is also present.

TABLE
TIME TO RUPTURE AT 1500° F. UNDER LOADS OF
17,500 AND 15,000 P. S. I. OF EXPERIMENTAL
MELTS VARYING IN MOLYBDENUM, TUNGSTEN AND
COLUMBIUM CONTENTS

A. Melts varying in molybdenum

Melt	C	Cr	Ni	Mo	W	Cb	Time to rupture in hours	
							15,000 p. s. i.	17,500 p. s. i.
S628.....	0.45	14.00	20.00	0.00	4.00	4.00	139	48
S629.....	0.45	14.00	20.00	1.00	4.00	4.00	406	90
S630.....	0.45	14.00	20.00	2.00	4.00	4.00	789	130
S631.....	0.45	14.00	20.00	3.00	4.00	4.00	930	145
S495.....	0.45	14.00	20.00	4.00	4.00	4.00	1,042	295
S632.....	0.45	14.00	20.00	5.00	4.00	4.00	651	172

B. Melts varying in tungsten

Melt	C	Cr	Ni	Mo	W	Cb	Time to rupture in hours	
							15,000 p. s. i.	17,500 p. s. i.
S633.....	0.45	14.00	20.00	4.00	0.00	4.00	304	58
S634.....	0.45	14.00	20.00	4.00	1.00	4.00	608	106
S635.....	0.45	14.00	20.00	4.00	2.00	4.00	699	128
S636.....	0.45	14.00	20.00	4.00	3.00	4.00	589	151
S495.....	0.45	14.00	20.00	4.00	4.00	4.00	1,042	295
S637.....	0.45	14.00	20.00	4.00	5.00	4.00	770	169

C. Melts varying in columbium

Melt	C	Cr	Ni	Mo	W	Cb	Time to rupture in hours	
							15,000 p. s. i.	17,500 p. s. i.
S620.....	0.45	14.00	20.00	4.00	4.00	0.00	121	37
S616.....	0.45	14.00	20.00	4.00	4.00	1.00	38	22
S617.....	0.45	14.00	20.00	4.00	4.00	2.00	290	108
S618.....	0.45	14.00	20.00	4.00	4.00	3.00	716	194
S495.....	0.45	14.00	20.00	4.00	4.00	4.00	1,042	295
S619.....	0.45	14.00	20.00	4.00	4.00	5.00	735	290

In connection with the table, it should be noted that the time of rupture has been ascertained in connection with various temperatures such, for example, as 1200° F. and 1300° F. but, for the sake of brevity, I have set forth only the rupture time at 1500° F. It might also be said that this temperature characteristically discloses the strength of the alloy at elevated temperatures.

In addition to the results set forth by the table it might also be noted that where all three of the constituents molybdenum, tungsten and columbium are present in the alloy, addition of one such constituent up to 6% produces a highly desirable alloy from the standpoint of strength at elevated temperature, structural stability under varying conditions, and workability. The table discloses that the strength of the alloy at the elevated temperature decreases as the amount of one of the constituents molybdenum, tungsten and columbium is decreased below 4%. The same result obtains when one of these elements is increased in amount above 4%. It, however, should be noted that where all three of these elements are present in the alloy within the ranges first above noted, a superior alloy is produced. Highly desirable results are, however, obtained where each of the constituents, molybdenum, tungsten and columbium is present within the

range of from about 3.00% to about 5.00% and in substantially equal amounts.

The carbon content of my new alloy is somewhat less critical than that of the last named constituents. The best results are obtained with alloys in which the carbon is within the range 0.30-0.60%. Either higher or lower carbon contents occasion a decrease in the strength of the alloy, although good results are obtained with alloys in which the carbon is as low as 0.20%.

The chromium and nickel content of the alloy produce the expected results. That is to say, these constituents add resistance to scale formation and corrosion at the high temperatures. They also contribute somewhat to the high temperature strength of the alloy. Whereas each of the constituents chromium and nickel may be included in amounts as low as about 10%, the two constituents must be present in the alloy in such amounts as to produce a stable austenitic alloy. That is to say, the aggregate of the nickel and the chromium content should equal about 26%. The amounts of nickel and chromium in the alloy, which I have referred to as the preferred embodiment of my invention, give the maximum strength at the elevated temperatures. Experiment has, however, shown that variations from this amount merely occasion a change in degree of the beneficial characteristics of the alloy. For this reason, conditions may arise where more or less chromium is desirable and changes in both the nickel and the chromium alloy may be made at some small sacrifice to strength. The indication, however, is that more than 20% chromium or more than 25% nickel is not required for optimum strength at the higher temperatures although where the alloy is to be employed for some special purpose, the chromium and nickel content may be increased above these percentages without detracting from its characterizing features, namely, strength at high temperatures, structural stability under varying conditions and workability.

The results set forth by the table and further investigation along the line of those results disclose—that I have previously suggested—that the preferred embodiment of my invention is a ferrous alloy containing approximately 0.45% carbon, approximately 14% chromium, approximately 20% nickel and molybdenum, tungsten and columbium in an equal ratio and in the neighborhood of about 4% each. The highly desirable characteristics of this particular alloy is, however, present in degree where the constituents are present within the ranges first above set forth. It should also be noted that while silicon and manganese are not essential elements in an alloy embodying my invention, they may be present in usual commercial amount. In connection with the silicon content in the alloy, it should also be understood that a certain amount is present due to the presence of silicon in the other ferro alloys employed in making the other alloying additions.

Alloys embodying my present invention are readily workable under commercial conditions and are capable of being easily fabricated by rolling and forging. It is, however, also to be noted that the alloy is highly effective and exhibits its desirable characteristics when employed in cast form.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A ferrous alloy containing carbon within the range from about 0.30% to about 0.60%, chromium within the range from about 12.00% to about 20.00%, nickel within the range from about 10.00% to about 30.00% and the combined elements, molybdenum, tungsten and columbium within the range from about 6.00% to about 18.00%, with substantially equal amounts of each such element and the principal part of the remainder iron.

2. A ferrous alloy containing carbon within the range of from about 0.20% to about 0.60%, chromium within the range from about 12.00% to about 22.00%, nickel in an amount somewhat in excess of the chromium, molybdenum, tungsten and columbium each within the range of from about 3.00% to about 5.00% and the principal part of the remainder iron.

3. A ferrous alloy containing carbon within the range of from about 0.30% to 0.60%, approximately 14.00% chromium, approximately 20.00% nickel, molybdenum, tungsten and columbium in substantially equal amounts and each approximately 4.00% and the principal part of the remainder iron.

4. A ferrous alloy consisting essentially of chromium and nickel in amounts sufficient to produce a stable austenitic alloy, carbon within the range of from about 0.20% to about 0.60%, approximately 4.00% each of molybdenum, tungsten and columbium and the remainder principally iron except for the usual contaminants in common amounts.

5. A ferrous alloy containing carbon within the range of from about 0.20% to about 0.60%, chromium within the range from about 10.00% to about 22.00%, nickel within the range of from about 10.00% to about 30.00%, molybdenum, tungsten and columbium each within the range of from about 2.00% to about 6.00% and the remainder principally iron.

6. A ferrous alloy containing carbon within the range of from about 0.20% to about 0.60%, chromium within the range of from about 12.00% to about 22.00%, nickel within the range of from about 10.00% to about 30.00%, substantially equal amounts of molybdenum, tungsten and columbium each within the range of from about 2.00% to about 6.00% with the remainder principally iron.

7. A ferrous alloy consisting of carbon within the range of from about 0.20% to about 0.60%, chromium and nickel each in amounts sufficient to produce a stable austenitic alloy with the aggregate of nickel and chromium content about

26.00% molybdenum, tungsten and columbium each present within the range of from about 2.00% to about 6.00%, silicon and manganese in at least usual commercial amounts with the remainder principally iron except for usual contaminants in common amounts.

8. A ferrous alloy containing carbon, chromium, nickel, molybdenum, tungsten and columbium, characterized by that the carbon is present within the range of from about 0.20% to about 0.60%, the chromium content is in excess of 10.00% and the nickel content is in excess of the chromium, and at least two of the three constituents, molybdenum, tungsten and columbium present in substantially equal amounts within the range of from about 2.00% to about 6.00%, and the other of the three last mentioned constituents present within the range of from about 2.00% to about 6.00%.

9. A ferrous alloy consisting of carbon within the range of from about 0.20% to about 0.60%, chromium in excess of 10.00%, nickel in excess of the chromium, molybdenum, tungsten and columbium each in amounts within the range of from about 2.00% to about 6.00%, silicon and manganese in at least usual commercial amounts and the remainder principally iron except for usual contaminants in common amounts.

10. A ferrous alloy containing carbon within the range of from about 0.20%, to about 0.60%, chromium and nickel in amounts sufficient to produce a stable austenitic alloy, the chromium within the range of from about 10.00% to about 22.00% and nickel within the range of from about 10.00% to about 30.00%, molybdenum, tungsten and columbium each present within the range of from 2.00% to 6.00% and with iron constituting the principal part of the remainder of the alloy.

11. A ferrous alloy containing carbon, chromium, nickel, molybdenum, tungsten and columbium with the carbon within the range of from about 0.20% to about 0.60%, the nickel and chromium contents together in excess of 26.00% and each in amounts sufficient to produce a stable austenitic alloy and at least two of the three constituents, molybdenum, tungsten and columbium, present in substantially equal amounts within the range of from 3.00% to 5.00% and the other of such three constituents present within the range of from about 2.00% to about 6.00% and with the remainder of the alloy principally iron.

GUNTHER MOHLING.