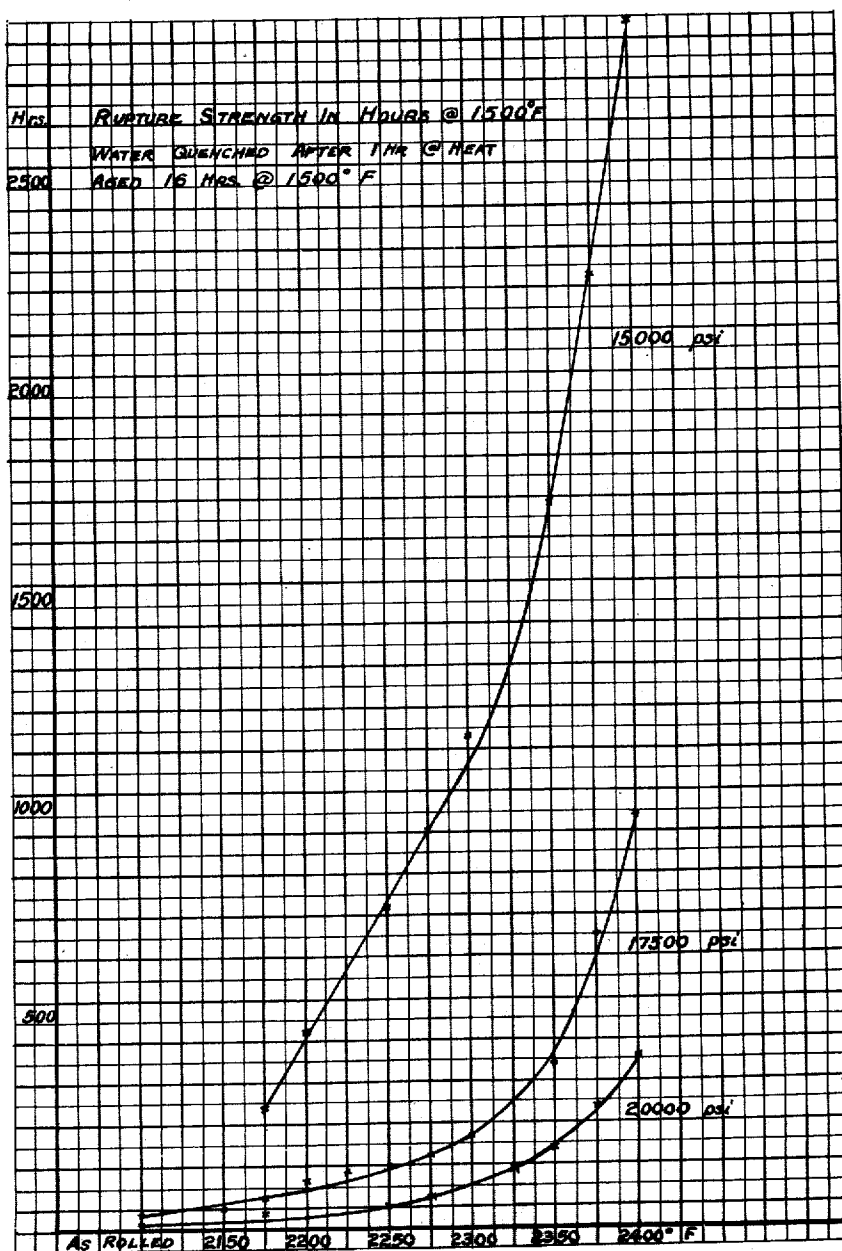


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METHOD OF INCREASING THE HIGH TEMPERATURE
STRENGTH OF HEAT-RESISTING ALLOYS
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METHOD OF INCREASING THE HIGH TEMPERATURE STRENGTH OF HEAT-RESISTING ALLOYS

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4 Claims. (Cl. 148—21.55)

1

This invention relates to an improvement in heat-resisting alloys and has for an object to provide procedure for increasing the resistance to deformation of such alloys when subjected to stresses at high temperatures.

A further object of the invention is to produce a procedure for increasing the high temperature, creep strength of heat-resisting alloys.

Heat-resisting alloy steels, like other steels, are increasingly susceptible to deformation at higher temperatures, with the result that the creep strength and the rupture strength of such steels decrease as the temperature of the steel increases. An object of the present invention, therefore, is to improve the high temperature characteristics of heat-resisting steels in order that they will be more effective for the intended purposes when subjected to load while existing at temperatures ranging from about 1300° F. to about 1550° F.

The above and other objects are accomplished by means of a procedure hereinafter set forth and defined.

In the drawing accompanying and forming a part hereof, I have included curves which visually indicate the improvement in the high temperature strength of heat-resisting alloys resulting from the treatment herein outlined as an embodiment of my invention.

This figure gives the results in hours to rupture, when samples heat treated from a series of temperatures were subjected to constant loads at a temperature of 1500° F.

My invention involves the discovery that the strength of heat-resisting alloys is improved and that such alloys are rendered more resistant to distortion at high temperatures by being subjected to a high temperature heat treatment followed by a rapid cooling such as is obtained by water quenching, where this procedure is followed by an aging treatment at a temperature within the range of from about 1300° F. to about 1550° F. That is to say, I have discovered that a treatment, such as is herein defined, will improve the high temperature strength—including the creep strength—of heat-resisting alloys.

While my invention may be effectively employed in connection with various types of heat-resisting alloys, I have carried on extensive in-

2

vestigations in connection with alloys such as those including

	Percent
Carbon	0.20- 0.60
5 Chromium	12.00-22.00
Nickel	10.00-30.00
Molybdenum	2.00- 6.00
Tungsten	2.00- 6.00
10 Columbium	2.00- 6.00

with the remainder principally iron, except for usual impurities in common amounts.

The graph reproduced in the accompanying drawing, is based on the application of my invention to a ferrous alloy containing 0.46% carbon, 0.61% manganese, 0.69% silicon, 13.96% chromium, 20.23% nickel, 3.65% molybdenum, 3.74% tungsten and 4.20% columbium, with the remainder principally iron except for the usual impurities in common amounts. This alloy was partially fabricated by rolling and forging into sections of the desired size and shape which were then heated to the temperatures indicated by the following table, water quenched, and then machined to form test pieces of the desired size. The test pieces were aged for approximately sixteen hours at 1500° F. before testing.

The high temperature heat treatment was in each instance accomplished within a gas muffle furnace and the section treated was maintained at the high temperature for about one hour. While the quenching at the high temperature is preferably a water quench, an oil or air quench may be employed. It should, however, be noted that rapid cooling is essential for satisfactory results and that a water quench appears to be the most effective.

The aging is also an important and an essential step in the procedure. Where the material is to be employed at a temperature within the range of from 1350° F. to 1550° F., the aging is accomplished at the temperature of use. That is to say, where the alloy is to be employed at a temperature of 1500° F., it is aged by being subjected to that temperature for approximately sixteen hours and then air-cooled. The aging treatment may be resorted to at any time after the high temperature solution treatment. The period of this treatment is not highly critical but about sixteen hours is indicated as desirable.

50

3

In the following table, I have set forth the temperature of quench, the load in pounds per square inch to which each test piece was subjected, the time to rupture in hours, the percentage of elongation under load and the percentage of reduction in area at the time of rupture. The tests were made while the test pieces were maintained at 1500° F. The test pieces had a gauge length of 4" and a cross-section of one-tenth of a square inch.

Temperature of quench	Load		
	15,000 p. s. i.	17,500 p. s. i.	20,000 p. s. i.
None (as rolled):			
Hours.....		40	4
Elongation..... percent.....		16	14
Reduction..... do.....		27	13
2150° F.:			
Hours.....		53	20
Elongation..... percent.....		21	
Reduction..... do.....		21	
2175° F.:			
Hours.....	287	73	46
Elongation..... percent.....	12	13	18
Reduction..... do.....	17	19	24
2200° F.:			
Hours.....	477	151	25
Elongation..... percent.....	15	16	
Reduction..... do.....	27	33	
2225° F.:			
Hours.....		123	
Elongation..... percent.....		18	
Reduction..... do.....		27	
2250° F.:			
Hours.....	764	143	48
Elongation..... percent.....	14	18	17
Reduction..... do.....	30	36	25
2275° F.:			
Hours.....	956	170	78
Elongation..... percent.....	12	15	18
Reduction..... do.....	30	36	36
2300° F.:			
Hours.....	1,178	250	35
Elongation..... percent.....	12	13	
Reduction..... do.....	28	32	
2325° F.:			
Hours.....			143
Elongation..... percent.....			10
Reduction..... do.....			32
2350° F.:			
Hours.....	1,733	396	112
Elongation..... percent.....	8	11	13
Reduction..... do.....	20	22	30
2375° F.:			
Hours.....	2,275	768	291
Elongation..... percent.....	3	3	12
Reduction..... do.....	8	5	29
2400° F.:			
Hours.....	2,888	996	410
Elongation..... percent.....	3	2	3
Reduction..... do.....	2	7	9

The foregoing table discloses that the high temperature strength of the alloy is increased as the temperature of the heat treatment is increased. It also discloses that the percentage of elongation and the percentage of reduction in area decreases with the temperature of the high temperature or solution treatment, with the result that the exact temperature employed will be governed by the particular alloy involved and the characteristics to be developed in the alloy.

I have also employed the procedure above-outlined on alloys such as above-defined but which also include from about 5% to about 30% of cobalt. The cobalt-bearing alloys respond effectively to the treatment, making it apparent that the rupture strength—at high temperatures—of austenitic chrome-nickel-cobalt, heat-resisting alloys is also improved by my procedure.

Analysis of the results discloses that the creep strength of the alloys is substantially increased by a short time temperature heat treatment at temperatures in excess of 2150° F. and that the creep strength is materially improved as the temperature of the short time heat treatment is increased above 2200° F. The creep strength or the ability to resist distortion under load is progressively

4

improved by a very high temperature heat treatment in excess of 2350° F. On the other hand, the material reduction in the ductility of the alloy occasioned by heat treatments above 2350° F. make it apparent that the range of utility of the alloy is somewhat reduced by such treatment, even though its rupture strength and its ability to resist distortion are increased.

For this reason, it is apparent that some further investigation may be required for the purpose of determining the particular temperature to be employed in connection with the high temperature solution treatment, in order to obtain the desired physical characteristics for each particular alloy. It, however, can be definitely stated that the high temperature strength of heat-resisting alloys of the chrome-nickel, austenitic type is materially improved by the treatment herein set forth, where the high temperatures employed are within the range of from about 2200° F. to about 2350° F. The accompanying graph also indicates that some improvement is obtained by solution treatment at lower temperatures.

It might also be stated that it is preferable to subject articles made from heat-resisting alloys to the high temperature heat treatment after rolling and/ forging operations have been completed. This is made more or less apparent by the effect of the heat treatment. It, however, may be stated that such fabrication operations as machining, grinding and drilling may be performed after the high temperature heat treatment and either before or after the aging treatment.

While I have outlined a procedure for improving the high temperature strength of heat-resisting alloys, it will be apparent that various changes in some of the individual steps of my improved procedure may be resorted to without departing from the spirit and scope of my invention as defined by the appended claims.

What I claim is:

1. A method of increasing the high temperature creep strength of an alloy containing chromium within the range of from about 12% to 22%, nickel within the range of from about 10% to 30% molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to 0.60% with the remainder substantially all iron, which consists in subjecting the same to a short time heat treatment at a temperature within the range of from about 2150° F. to 2400° F., followed by a rapid cooling and then subjecting the same to a heat treatment within the range of from about 1350° F. to about 1550° F. for approximately sixteen hours.

2. A method of increasing the load carrying ability of an alloy consisting of chromium within the range of from about 12% to 22%, nickel within the range of from about 10% to 30%, molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to about 0.60% with the remainder substantially all iron, which consists in subjecting the same to a temperature of at least 2150° F., followed by a quick cooling and then subjecting such alloy to an aging heat treatment within the range of from about 1350° F. to about 1550° F. and for approximately sixteen hours.

3. A method of increasing the resistance to deformation, at elevated temperatures, of at least a partially fabricated article made from an alloy consisting of chromium within the range of from

5

about 12% to 22%, nickel within the range of from about 10% to 30% molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to 0.60% with the remainder substantially all iron, which consists in subjecting such article to a short time heat treatment within the range of from about 2150° F. to 2400° F., followed by a water quench and then subjecting the same to an aging treatment for approximately sixteen hours at a temperature within the range of from about 1350° F. to about 1550° F.

4. A method of improving the high temperature, rupture and creep strength of an article made from an alloy consisting of chromium

6

within the range of from about 12% to 22%, nickel within the range of from 10% to 30%, molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to 0.60% with the remainder substantially all iron, which consists in subjecting such article to a heat treatment at a temperature in excess of 2150° F., followed by a water quench and then, after complete fabrication of such article, subjecting it to a heat treatment for approximately sixteen hours at about the temperature to which it will be subjected during use.

GUNTHER MOHLING

Certificate of Correction

Patent No. 2,401,580.

June 4, 1946.

GUNTHER MOHLING

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 3, line 70, before the word "temperature" insert *high*; column 4, line 27, for "and/" read *and/or*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of August A. D. 1946.

[SEAL]

LESLIE FRAZER,

First Assistant Commissioner of Patents.

5

about 12% to 22%, nickel within the range of from about 10% to 30% molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to 0.60% with the remainder substantially all iron, which consists in subjecting such article to a short time heat treatment within the range of from about 2150° F. to 2400° F., followed by a water quench and then subjecting the same to an aging treatment for approximately sixteen hours at a temperature within the range of from about 1350° F. to about 1550° F.

4. A method of improving the high temperature, rupture and creep strength of an article made from an alloy consisting of chromium

6

within the range of from about 12% to 22%, nickel within the range of from 10% to 30%, molybdenum, tungsten and columbium each within the range of from about 2% to 6%, carbon within the range of from about 0.20% to 0.60% with the remainder substantially all iron, which consists in subjecting such article to a heat treatment at a temperature in excess of 2150° F., followed by a water quench and then, after complete fabrication of such article, subjecting it to a heat treatment for approximately sixteen hours at about the temperature to which it will be subjected during use.

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