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CREEP RESISTANT CHROMIUM STEEL

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This invention relates to ferritic chromium steels. Such steels have been used to a large extent in recent years for creep-resistant applications such as turbine and compressor discs in gas turbines. The normal procedure has been to harden and temper the alloy and it has been shown by numerous workers that the composition of the steel is critical if optimum properties are to be obtained, it being generally accepted that if the composition of the steel is such that it is not wholly austenitic at the hardening or solution temperature, the final structure of the steel will be a tempered martensite with areas of "free ferrite" and if these areas of "free ferrite" are extensive, they have a deleterious effect on the creep strength and transverse ductility of the material.

	C	Mn	Si	Cr	Mo	Nb	V	Ti	N	B	W
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
W216.....	0.09	0.37	0.51	10.4	0.37	0.32	0.77	0.001	0.001	0.005	0.005
W226.....	0.06	0.6	0.35	10.5	0.45	0.3	0.06	0.001	0.001	0.008	0.008
W318.....	0.09	0.8	0.3	11	0.5	0.4	0.2	0.001	0.001	0.008	0.008
W354.....	0.05	0.8	0.4	13	1	1.5	0.25	0.1	0.1	0.13	1

It is an object of the present invention to obviate the close control of composition.

According to this invention chromium steels which are essentially ferritic (for example containing at least 60% ferrite) at normal solution or hardening temperatures (for example 1000–1300° C.) and so do not harden on quenching, are subsequently treated to improve or provide creep strength.

The treatment referred to may consist of cold or warm working the soft ferritic steel or by a combination of solution hardening and precipitation hardening of the material or by all three mechanisms.

Cold or warm working may comprise heating the solution treated material to the desired temperature within a suitable range, e.g. 20°–700° C., and then working it by rolling, stamping, pressing or any other means to a reduction in thickness or diameter of, for example 1% to 10%.

Solution hardening or precipitation hardening may be effected with the use of precipitation hardening additions, such for example, as molybdenum, tungsten, niobium, tantalum, titanium or other suitable known materials.

Further features of the invention will be apparent from the following description of detailed methods, given by way of example of carrying out the invention.

Steels suitable for cold or warm working as above described may have any composition within the specification

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below, but the balance of composition must be such that the steel is essentially ferritic (e.g. at least 60%) at 1000°–1300° C.

	Percent
5 Carbon.....	0.05–0.3
Manganese.....	0.05–2.0
Nickel.....	0–4
10 Silicon.....	0.05–1.0
Cobalt.....	0–4
Chromium.....	9–20
Tungsten.....	0–3*
Molybdenum.....	0–3
15 Niobium and tantalum.....	0–2
Titanium.....	0–2
Vanadium.....	0–2
Nitrogen.....	0.001–0.2
20 Boron.....	0–0.05

*At least 0.7% total of these elements for adequate creep strengths.

25 In addition up to 0.5% total of any of the stronger de-oxidisers such as aluminium, cerium, magnesium could be present if desired but these are not essential.

Example of alloys within these ranges are:

The above alloys tested at 30 tons/sq. in. at 500° C. gave the following figures:

	Percentage strain at 100 hours	
	(a) O.Q. 1,200° C., tempered at 500° C.	(b) O.Q. 1,200° C., warm worked 5% at 500° C.
40 W216.....	0.27	0.09
W226.....	0.28	0.08
W318.....	0.23	0.09
W354.....	greater than 1.	0.05

For solution hardening and precipitation hardening materials the specification is as above described with the exception of:

	Percent
55 Molybdenum.....	0–6*
Tungsten.....	0–6
Vanadium.....	0–2
Niobium and tantalum.....	0–2†
Titanium.....	0–2†

*Solution hardening addition, totalling at least 1.5%.
†Precipitation hardening addition.

These steels may also be warm worked but satisfactory creep strength can be achieved without this process. Examples:

	C	Mn	Si	Cr	Mo	W	V	Nb	N	B
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
WEX352.....	0.05	0.8	0.3	13	1	1	0.2	0.5	0.1	0.01
WEX409.....	0.05	0.8	0.3	13	2	2	0.2	0.5	0.1	0.01
WEX551.....	0.05	0.8	0.3	13	2	2	0.2	0.25	0.1	0.01

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The alloys are normally solution treated at 1000–1300° C. and air, oil or water quenched. They are subsequently aged in the temperature range 500–700° C.

The above examples, when oil quenched at 1200° C., aged for 20 hours at 650° C., and tested at 30 tons/sq. in. at 500° C. gave the following figures:

Material	Percent of Ferrite at 1,200° C.	Strain at 100 hours, percent
WEX352	80	0.065
WEX409	95	0.035
WEX651	65	0.096

What we claim is:

1. A normally non-hardenable chromium steel containing at least 60% ferrite at 1000–1300° C., at least one element selected from the group consisting of 0–6% molybdenum, 0–6% tungsten and 0–2% vanadium wherein the elements are present in a total amount of at least 1.5% for the purpose of solution treatment wherein said steel has been treated to improve creep strength by the steps comprising solution treating the steel at a temperature in the range of 1000–1300° C., quenching the steel for the purpose of effecting solution treatment thereof and working the steel at a temperature within the temperature range of 20°–700° C. to reduce the thickness thereof substantially 1%–10%.

2. The steel as defined in claim 1 containing at least

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one element selected from the group consisting of 0–2% titanium, and 0–2% niobium and tantalum wherein said elements are present in an effective amount for producing precipitation hardening and wherein the steel has been treated to improve creep strength by the step comprising aging the steel in a temperature range of 500°–700° C. after the steel has been worked to reduce the thickness thereof.

3. The steel as defined in claim 1 containing at least one element selected from the group consisting of 0–2% titanium, and 0–2% niobium and tantalum wherein said elements are present in an effective amount for producing precipitation hardening and wherein the steel has been treated to improve creep strength thereof by the step comprising aging the steel at a temperature range of 500°–700° C. following quenching of said steel and before working of said steel to reduce the thickness thereof.

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