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FERROUS ALLOYS FOR HIGH TEMPERATURE USE

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This invention relates to alloys intended for use in the production of articles which in use are subjected to high temperatures.

According to this invention alloys comprise:

	Percent
Carbon	0.05–0.45
Manganese	up to 2
Silicon	up to 1
Chromium	13–23
Nickel	[1] 0–30
Cobalt	[1] 0–30
Boron	0.001–0.05
Tungsten	0–5
Molybdenum	0–5
Niobium	0–5
Tantalum	0–5
Titanium	0–5
Vanadium	0–5
Iron and impurities	Balance

[1] Nickel and cobalt together shall not exceed 45%.

The total of tungsten, molybdenum, niobium, tantalum, titanium, vanadium being between 5% and 10% and at least two of these elements being present.

According to a further feature of the invention any

one or all of the following more restricted ranges may be substituted for those given above:

	Percent
Carbon	0.15–0.45
Manganese	0.5–1.5
Silicon	0.15–0.75
Chromium	15–23
Nickel	13–28
Cobalt	[1] 22–28
Boron	0.002–0.04
Tungsten	0.5–3.5
Molybdenum	0.5–3.5
Niobium	0.5–3.5
Tantalum	0.5–3.5
Titanium	0.5–3.5
Vanadium	0.5–3.5

[1] (Or alternatively 0–3%.)

In the above mentioned ranges the amount of iron present is preferably less than 50%.

A feature of the invention is that alloys according to the invention are particularly suitable for warm working, that is to say, working at temperatures between about 500° C. and 900° C., to give a reduction in thickness of up to about 20%. A surprising result of warm working is that the rupture-time at a given stress and temperature is significantly raised. Warm working as is usually the case, preferably follows solution heat treatment. Solution heat treatment usually involves a treatment in which a steel is heated to a uniform temperature above about 1000° C. and is maintained at that temperature for a suitable period of time.

Examples of alloys, in which the amounts are given by weight percent, according to the invention are:

Alloy	L. 641	L. 729	L. 915	L. 1299	L. 908	L. 899	L. 1293
Carbon	0.4	0.4	0.25	0.25	0.2	0.20	0.20
Manganese	0.8	0.8	0.8	1.0	1.0	1.0	1.0
Silicon	0.5	0.5	0.3	0.3	0.3	0.3	0.5
Nickel	15.0	15.0	15.0	15.0	25.0	25.0	25.0
Cobalt	25.0	25.0	25.0	25.0			
Chromium	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Tungsten	2.5	2.5	2.2	3.0	1.0	2.0	1.5
Molybdenum	2.0	2.0	2.3	3.0	3.0	3.0	2.6
Niobium	3.0	3.0	2.2			2.0	2.0
Vanadium			2.3			1.0	
Boron	0.03	0.003	0.03	0.03	0.03	0.03	0.03
Titanium				1.0	2.0		
Iron and Impurities	Balance	Balance	Balance	Balance	Balance	Balance	Balance

The following table shows properties of these alloys and the very substantial gains in creep and rupture properties resulting from warm working.

Material	Stress, Tons/sq. in.	Temperature, ° C.	Time in hours to give 1% elongation	Fracture	Minimum Creep rate per hr. $\times 10^{-5}$	Elongation, percent at fracture
L.641 [1]	16	750	18	339	22	18
L. 641 [2]	16	750	620	2,022	0.37	3
L. 641 [1]	10	800	60	1,140	3.2	17
L. 641 [2]	10	800	1,120	3,117	0.1	10
L. 729 [1]	16	750	10	225	31	14
L. 729 [2]	16	750	310	1,298	1	10
L. 915 [2]	18	750	440	917	0.5	2
L. 915 [2]	14	800	30	435	3.6	7
L. 1299 [2]	19	750	372	372	1.0	1.0
L. 1299 [2]	14	800	195	501	1.5	2.0
L. 1299 [2]	9	870	165	263	1.5	2.9
L. 908 [2]	18	750		305	1.2	7
L. 899 [2]	18	750		142		3
L. 1293 [2]	17	750		34		2
L. 1293 [2]	9	800	320	527		4

[1] Oil quenched 1280° C.
[2] Oil quenched 1280° C. Warm worked at 700° C., to give 5 to 10% reduction in thickness

Generally speaking increased additions of cobalt in alloys of the kind herein specified result in increased creep strength. However, the use of boron materially assists in reducing the necessary quantity of cobalt. For instance in alloys of this general type, but without boron, the stress in tons per square inch for 300 hour rupture at 750° C., was about 13 with a proportion of 10% cobalt and this increased, more or less linearly, to about 19 with cobalt gradually increased to about 60%. When a proportion of 0.03% boron and 0% cobalt was present the stress was 18 tons per square inch and this increased substantially linearly with increased quantities of cobalt to about 20.5 tons per square inch with cobalt gradually increased to only about 25%. In the alloys according to this invention it is desirable that the cobalt content should not exceed 25% particularly when boron is present in proportions of 0.03% or over, as such alloys are difficult to forge.

To avoid the use of scarce or expensive materials it will be noticed that cobalt and niobium may be omitted and titanium substituted for the latter as in alloy L. 908. The resulting properties are outstanding for so cheap an alloy. Titanium may be avoided in these cobalt-free alloys if niobium is used, for example alloy L. 899.

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

1. Alloys comprising:

	Percent
Carbon	0.15–0.45
Manganese	0.5–1.5
Silicon	0.15–0.75
Chromium	15–23
Nickel	13–28
Boron	0.002–0.04
Tungsten	0.5–3.5
Molybdenum	0.5–3.5

together with at least one metal selected from the group consisting of niobium, titanium and vanadium, the content of any single element of said group being 0.5–3.5%, the total of tungsten, molybdenum and the total content of said group being between 5 and 10%, and the remainder being substantially all iron and incidental impurities.

2. Alloys according to claim 1, containing in addition 22–28% cobalt, the total content of nickel and cobalt not exceeding 45%.

3. Alloys comprising the following constituents in substantially the proportions specified: 0.2% carbon, 1% manganese, 0.3% silicon, 25% nickel, 20% chromium, 1% tungsten, 3% molybdenum, 0.03% boron, and 2% titanium, the remainder being substantially all iron and impurities.

4. Alloys comprising the following constituents in substantially the proportions specified: 0.25% carbon, 1% manganese, 0.3% silicon, 15% nickel, 25% cobalt, 20% chromium, 3% tungsten, 3% molybdenum, 0.03% boron, and 1% titanium, the remainder being substantially all iron and impurities.

5. Alloys according to claim 1 which have been subjected to warm working at temperatures between about 500° C. and 900° C.

6. Alloys according to claim 5 which prior to warm working have been subjected to solution heat treatment.

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