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(54)

Austenitic alloy steel and bar, billet, wire, slab, plate, sheet, tube or forgings.

(57)

An austenitic alloy of iron, chromium, nickel and aluminium containing

15 to 20% chromium,

15 to 20% nickel and

0 to 5% cobalt but the content of nickel

and cobalt being such that $\frac{Co}{2} + Ni$ is from 15 to 20%,

where Co is the percentage of cobalt, and Ni is the percentage of nickel,

2 to 4 % aluminium,

0.02 to 0.15% carbon,

0.1 to 0.8 % titanium,

0.2 to 2.0 % silicon,

0.2 to 2.0 % manganese,

and optionally from 0 to 0.8% of hafnium or of zirconium the balance being iron and incidental amounts of other alloying elements.

The alloy provides resistance to oxidation and sulphidation together with weldability and hot strength.

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AUSTENITIC ALLOY STEEL AND BAR, BILLET, WIRE,
SLAB, PLATE, SHEET, TUBE OR FORGINGS

The present invention relates to austenitic alloys of iron, chromium and nickel, containing additions of aluminium and titanium, with or without additions of either hafnium or zirconium.

5 The present invention provides an austenitic alloy of iron, chromium, nickel and aluminium containing

15 15 to 20 % chromium,

15 15 to 20 % nickel and

10 0 to 5 % cobalt but the content of nickel and cobalt being such that $\frac{Co + Ni}{2}$ is from 15 to 20% where Co is the percentage of cobalt, and Ni is the percentage of nickel,

2 to 4 % aluminium,

15 0.02 to 0.15 % carbon,

0.1 to 0.8 % titanium,

0.2 to 2.0 % silicon,

0.2 to 2.0 % manganese,

and optionally from 0 to 0.8 % of hafnium or of zirconium
20 the balance being iron and incidental amounts of other alloying elements.

In our British Patent applications Nos. 8006738 and 8006739 we disclosed ferritic alloys of iron, chromium and aluminium containing titanium and hafnium

respectively and providing resistance to oxidation.
It has been found that the ferritic alloys described in
these applications, although possessing adequate
oxidation and/or sulphidation resistance, have
5 insufficient hot strength for use in some environments
or fail to find application due to their inherently
poor welding and fabricating characteristics.

Those skilled in the art will appreciate
that a sufficient amount of chromium must be present
10 to provide a basic oxidation resistance. On the
other hand, since a low nickel content is desirable
from the point of view of sulphidation resistance,
to maintain an austenitic structure the chromium
content should be kept to the minimum consistent
15 with adequate oxidation resistance. The additional
benefit contributed by small but significant
additions of either hafnium or zirconium does in
some instances appear worthwhile. The provision
of titanium stabilises the alloy against
20 intercrystalline corrosion effects. A high silicon
content, whilst possibly being beneficial as
regards oxidation resistance, is to be avoided
on account of its possible embrittlement effect.
Similarly, a sufficiently high manganese content
25 to be effective as a delta ferrite suppressor
is not advisable on account of its detracting from

3.

oxidation resistance.

Up to 5% of cobalt is permitted, fulfilling essentially the same purpose as nickel. When cobalt is present it can be regarded as a replacement on a
5 2:1 basis for nickel.

Optionally up to 0.8%, e.g. 0.05 to 0.80%, of hafnium or of zirconium may be included. The balance of the composition is iron and incidental amounts of other alloying elements not specifically
10 added. The presence of incidental amounts of copper, cobalt, molybdenum and tungsten above the impurity level may be tolerated provided they are not present in excess. Other elements such as sulphur and phosphorus may be present but these are
15 impurities which are not desirable.

In all cases, however, the composition balance is such as to ensure a virtually non-magnetic alloy.

The alloys may be manufactured by processes normally used for making alloys of this general type.
20 For instance, they may be made by induction melting, either in air or using inert atmosphere or vacuum as appropriate, cast into ingots and subsequently forged or rolled into billet or slab prior to working down to plate, sheet, strip, bar wire, tube or any
25 other commercially saleable form.

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In a typical small scale process for producing an austenitic steel of this invention, a charge of high purity iron, nickel pellet and low carbon ferrochromium is melted down in a basic lined induction furnace, either in air under a base slag, or under an inert atmosphere or in vacuo, without slag, as appropriate. When completely melted, the appropriate additions of aluminium, ferrotitanium (and hafnium or zirconium or other special metal addition) are added, in that order, the metal brought to temperature and cast into an appropriate ingot mould.

The invention will be illustrated by the following examples. Alloys according to the invention were prepared having the compositions given below by the process described above. The size of the melts was 10 kg each, giving a 2½" (60 mm) square ingot which was heated to 1150° C and forged under a 10 cwt. hammer to produce suitable test bar.

Example	C	Si	Mn	Cr	Ni	Al	Ti	?	Hf
A	0.077	0.73	0.95	17.64	17.40	2.48	.41	-	-
B	0.078	0.72	0.95	17.68	17.48	2.48	.39	-	-
C	0.064	0.74	0.94	17.52	17.48	2.70	.41	-	.52

5 The resistance of these steels to oxidation was compared by the following test procedure:

Specimens some $\frac{1}{2}$ " (13 mm) in diameter by $1\frac{1}{4}$ " (30 mm) long were machined from bar and ground to a 120 grit finish. They were washed and cleaned in alcohol
10 prior to test.

The test was of relatively short duration but involved cycling between ambient and test temperature. The test chamber was an alumina tube 2" (50 mm) internal diameter in which the sample was positioned
15 across an open ended alumina boat. Heating was by means of the concentric electric furnace, the temperature being measured by reference to a noble metal thermocouple, the hot junction of which was immediately above the specimen. The test atmosphere
20 was produced by burning natural gas using excess air over that required for combustion, the flow rates being 1.4 cubic foot and 14 cubic foot (0.04 and 0.4 cubic metres) per hour respectively for gas and air. The combustion product, a mixture of nitrogen, oxygen,
25 carbon dioxide and steam, was preheated to test temperature before passing through the test chamber;

test temperature was established prior to inserting the sample so that heating was rapid. Each test cycle was for six hours; after this the specimens were removed from the test chamber and cooled in a closed container so that any scale which became detached was collected. When cold, the specimen was weighed, together with any detached scale and then scrubbed with a stiff bristle brush to remove any loosely adherent oxide prior to reweighing to obtain the starting weight for the next cycle. The whole procedure was repeated for a total of seven cycles and the total gain in weight, that is the sum of the individual gains, expressed as milligrams per square centimetre for the 42-hour period, using the original surface area for the untested specimen, was taken as the scaling index.

The scaling indices for the steels tested were as follows:

	<u>Example A</u>	<u>Example B</u>	<u>Example C</u>	<u>Typical AISI 310</u>
1100°C	7.7	2.3	4.3	6
1150°C	52.3	30.5	34.2	11
1200°C	119.3	66.6	103.1	17
1250°C	133.0	141.1	146.9	30

Thus for service at temperatures up to 1100°C in oxidising atmospheres the alloys covered by the present application are at least equivalent to the standard material known as AISI 310. None of the materials were suitable for use at higher temperatures.

To make a rough assessment of resistance to sulphidation, similar test specimens to those used above were prepared and weighed and then half immersed in an intimately ground mixture of 90% sodium sulphate and 10% sodium chloride contained in alumina boats. These were then placed on a stainless steel tray, with samples of a number of other different materials similarly treated, and the whole placed in a muffle furnace and heated to 900°C for six hours. The tray was then withdrawn, the samples allowed to cool, cleaned as far as possible in hot water and then cathodically descaled in a bath of molten sodium hydroxide at 350°C, using a current of 9 amperes for 20 minutes. After descaling and thorough washing, they were dried in alcohol and reweighed. Losses in weight, expressed in mgm. per sq.cm., were as follows:-

<u>Example</u>	<u>Weight Loss</u>
A	4.4 .
B	1.3
C	2.2

5 These figures were as low as those found with
any other steel tested, including the special iron-
chromium-aluminium alloys of our copending applic-
ations referred to above. In general, alloys with
high nickel contents but not containing aluminium
10 failed catastrophically, examples being:

<u>Sample</u>	<u>Weight Loss</u>
A.I.S.I. 310 (25 Cr-20 Ni)	1114
Ni-Cr Alloy (80 Ni-20 Cr)	1447

15 To check the relative hot strengths of the
proposed materials, hot tensile tests were carried
out at a number of temperatures, with a strain rate
of three inches per minute. These indicated the hot
strength to be similar to that of A.I.S.I. 310 and
20 considerably higher than that of the iron-chromium-
aluminium alloys.

Laboratory scale welding trials, with deposits
laid down on the edges of 1" x $\frac{1}{4}$ " coupons, indicated
freedom from cracking within the parent metal.

25 The alloys exemplified above can be seen to

provide a weldable, relatively strong series of alloys, similar in general characteristics to the well known A.I.S.I.310 heat resisting material but having the advantage of resistance to sulphidation attack exhibited by the iron-chromium-aluminium alloys. Alternatively, they exhibit the resistance to sulphidation attack of the iron-chromium-aluminium alloys but have the advantage over these of higher hot strength and weldability, making them suitable for tube manufacture for use in difficult environments without the need for cladding and rendering them capable of being used in welded fabrications, their only disadvantage being a lower resistance to pure oxidation as compared with the more advanced iron-chromium-aluminium alloys. These latter properties, however, can only adequately be realised with adequate support in applications such as electric resistance elements.

CLAIMS:

1. An austenitic alloy of iron, chromium, nickel and aluminium characterised by containing

15 to 20 % chromium,

15 to 20 % nickel and

0 to 5 % cobalt but the content of nickel and cobalt being such that $\frac{Co}{2} + Ni$ is from 15 to 20% where Co is the percentage of cobalt, and Ni is the percentage of nickel,

2 to 4 % aluminium,

0.02 to 0.15 % carbon,

0.1 to 0.8 % titanium,

0.2 to 2.0 % silicon,

0.2 to 2.0 % manganese,

and optionally from 0 to 0.8 % of hafnium or of zirconium the balance being iron and incidental amounts of other alloying elements.

2. An alloy as claimed in claim 1 further characterised by containing from 17 - 20% chromium.

3. An alloy as claimed in claim 1 or Claim 2 further characterised by containing 17 - 20% nickel.

4. An alloy as claimed in any preceding claim further characterised by containing titanium such that the content is not less than 4 times the carbon content but not more than 0.8%.

5

5. An alloy as claimed in any preceding claim further characterised by containing about 2.5% aluminium.

10

6. An alloy as claimed in any one of claims 1 to 5 further characterised by containing 0.05 to 0.8% hafnium.

7. An alloy as claimed in any one of claims 1 to 5 further characterised by containing 0.05 to 0.8% zirconium.

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8. Bar, billet, wire, slab, plate, sheet tube or forgings characterised by being in an alloy as claimed in any one of the preceding claims.

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EUROPEAN SEARCH REPORT

0050408

Application number

EP 81 30 3998

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>GB - A - 1 361 055</u> (SUMITOMO KINZOKU KOGYO K.K.) * claim 1 * --	1,4,7	C 22 C 38/50
	<u>GB - A - 371 334</u> (S.A. DE COMMEN-TRY FOURCHAMBAULT & DECAZEVILLE) * claims 1,2 * --	1	
	<u>GB - A - 404 876</u> (S.A. DE COMMEN-TRY FOURCHAMBAULT & DECAZEVILLE) * claim 1 * --	1	TECHNICAL FIELDS SEARCHED (Int.Cl. ³) C 22 C 38/50 38/52 38/40
	<u>DE - A - 2 648 968</u> (NIPPON STEEL CORP.) * claims 1,7 * --	1	
	<u>SU - A - 589 281</u> (KAZIMIROVSKAIA et al.) * claim *	1	CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons
	<u>GB - A - 465 916</u> (HATFIELD et al.) * claim 1 * -- ./.	1	&: member of the same patent family, corresponding document
X The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25-01-1982	Examiner LIPPENS



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EUROPEAN SEARCH REPORT

0050408
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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>GB - A - 1 570 026</u> (HENRY WIGGIN & CY. LTD.) * claim 1; page 2, lines 28-31 * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)