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Description

The present invention relates to relatively low-cost stainless steel alloys used for casting applications, e.g. turbine and turbocharger housings, exhaust manifolds, combustion chambers, etc. having satisfactory corrosion resistance and other properties at room and elevated temperatures in the operating range up to 2000°F (1093°C).

Cast articles of this type, in particular, automotive or aircraft turbocharger housings, are subject to elevated operating temperatures up to about 2000°F (1093°C), and must be able to contain a turbine wheel generating very high rotational speeds. In turbochargers for truck diesel engines, the temperature reaches 1300-1400°F (704-760°C) resulting in housing metal temperatures of 1200-1300°F (649-704°C). In passenger car turbochargers, however, the operating temperatures extend up to the 1750-2000°F (954-1909°C) range, which results in metal temperatures of 1550-1950°F (843-1066°C) at the gas inlet or tongue section of the turbocharger housing since this inlet area is within a few degrees of the turbine exhaust temperature and is insulated so that heat is not dissipated rapidly. It is in metal sections such as this gas inlet area of an automotive turbocharger where the exhaust gas initially contacts the turbocharger, that thermal cracking is encountered, unless relatively expensive stainless steel casting alloys are employed.

The commercially available HD alloy which is inherently a duplex material contains about 26-30% chromium and 4-7% nickel, however, because of the relatively low nickel content, it is subject to sigma phase formation, which becomes very brittle and gives rise to thermal cracking when used at elevated temperatures, particularly when the cast material is subjected to thermal cycling. In the past, the shortcomings of the HD series alloys have been overcome by adopting a stainless steel casting alloy of higher nickel content such as commercially available high nickel ductile iron casting alloys. Examples of these are NiResist (Trade Mark) developed by International Nickel Company, or HK30, a chromium-nickel-iron stainless steel alloy containing approximately 30% chromium and 20% nickel, balance essentially iron. The HK series stainless steel alloys in general have about 18-22% nickel and are fully austenitic. The HK stainless steel alloys are some of the strongest stainless steel casting alloys, in terms of creep strength, however, while meeting the high temperature property requirements for turbocharger housings, they are quite expensive and present casting difficulties because of their high nickel content.

US Patent No. 3,969,109 Tanczyn, discloses a stainless steel wrought alloy having a composition of 21-30% Cr, 2-10% Ni, 0.25-0.45% C, 0.01-2.5% Mn and 0.35-0.55% N, in which high temperature strength and resistance to sulphidation and oxidation at elevated temperatures are obtained by reducing the carbon and the manganese contents of the commercial 21-4 stainless steel alloys. This patent, however, relates to wrought alloys which are claimed to be fully austenitic. They are not therefore

cast stainless steel duplex alloys since they are wrought materials and do not enjoy the advantage of a ferrite content.

It is an object of the present invention to provide a low-cost stainless steel casting alloy which is resistant to thermal cracking, and exhibits good room temperature strength and high creep strength and burst resistance at operating temperatures in the range of up to 1950°F (1066°C).

It is also an object of the present invention to provide a relatively low cost stainless steel casting alloy with improved casting characteristics.

It is a further object of the present invention to provide an improved and cost efficient method for casting stainless steel articles for high temperature service.

According to the present invention, there is provided a cast stainless steel article having a duplex metallurgical structure of about 20-80% ferrite, the balance being austenite and being substantially devoid of sigma phase, the article comprising essentially in weight percent:-

27 to 31% chromium

4 to 6% nickel

0.2 to 0.5% nitrogen

0.2 to 0.4% carbon

0.5 to 1.5% niobium (columbium)

0.2 to 0.4% sulphur

and optionally

up to 2% silicon

up to 1.0% manganese

up to 1.0% molybdenum

up to 0.5% copper

up to 0.2% aluminium

up to 0.03% phosphorus

the balance being iron with incidental impurities.

If included, the manganese and/or molybdenum would be present as a sulphide former and one or other would be selected.

Such an article may have good resistance to thermal cracking when subjected to cycling between room temperature and a service temperature of 1500-1950°F (816-1066°C) and which, in the solution treated condition, may be resistant to oxidation corrosion, may have a room temperature tensile strength of at least 75,000psi (52.7 kg/mm²) and at least about 7% elongation.

In accordance with the present invention, therefore a duplex stainless steel alloy, that is, a two phase alloy having both ferritic and austenitic structure, can be used for cast metal parts subject to high operating temperatures, such as automobile turbocharger housings, gasoline engine exhaust manifolds, and cast furnace or combustion chamber components, thereby combining the high temperature properties of the austenitic phase with the castability and low thermal expansion characteristic of the ferritic phase.

It has been found that the controlled addition of nitrogen to low nickel duplex stainless steels, greatly increases their thermal cracking resistance and effectively improves the stainless steel alloys in a manner normally achieved by higher nickel additions, gaining the strength characteristics, the corrosion

resistance, and the creep strength of austenitic stainless steels. The resistance of the alloys of the present invention to thermal cracking (due to higher strength and low thermal expansion), by the addition of nitrogen rather than nickel, provides a stainless steel casting alloy functionally equivalent to the HK series stainless steels, at substantial cost savings.

Preferably the article has a Nitrogen content of 0.3-0.4 weight percent.

Preferably, the article has a composition including by weight: 27-31% Cr, 4-6% Ni, 0.2-0.4% C, 0.5-1.0% Mn, up to 1.0% Mo, 1-2% Si, 0.5-1.5% Nb (niobium or columbium), 0.3-0.4% N up to 0.03% P, 0.2-0.4% S, up to 0.50 Cu, up to 0.20% Al, the balance being iron.

Preferably the article has a duplex structure of 40-60% ferrite, the balance being austenite.

A preferred composition for the article, by weight may be 31% chromium, 5% nickel, 0.24% carbon, 0.65% manganese, 1% silicon, 0.35% molybdenum, 0.3% sulphur, 0.9% columbium (niobium), 0.32% nitrogen, the balance being iron.

According to another aspect of the invention, there is provided a method for producing a cast stainless steel article having a duplex metallurgical structure of about 20-80% ferrite, the balance being austenite, comprising the steps of: melting a commercial steel mixture to a target chemistry as defined above for the article in accordance with the invention, heating the steel alloy mixture to a temperature of about 2850-2900°F (1566-1593°C) for a time sufficient to homogenise the melt; pouring the steel at a tap temperature of about 2850°F (1566°C) into molds employing gates designed to minimise porosity; and allowing the article to solidify.

Preferably, the method includes subjecting the cast article to a solution treatment at about 2000-2200°F (1093-1204°C) for 1-4 hours or longer to redistribute $M_{23}C_6$ carbide (where «M» is essentially chromium). Preferably, the method includes the step of removing the gates by snap breaking after the cast article has cooled to room temperature and before the solution treatment. Preferably, the solution treated article is air cooled following the solution treatment and is preferably also subjected to a strengthening treatment at about 1400-1600°F (760-871°C) for up to 24 hours.

Thus, a preferred stainless steel casting composition for turbine housings, in accordance with the present invention, is an H-series stainless steel with a relatively low nickel content which is modified with nitrogen to obtain a ferrite/austenite duplex structure having ferrite in the range of 20-80%, preferably 40-60% ferrite, having improved resistance to thermal cracking. The amount of ferrite present in the alloy microstructure is determined by the chemistry of the alloy, the fabrication technique, and the heat treatment employed. It is not believed that the ferritic phase contributes to the high temperature properties of the cast alloy.

Without a solution treatment, stainless steel castings according to the invention may be brittle and hence some form of solution treatment is preferable. The brittleness prior to heat treatment has been found to enhance the steel casting method of the

present invention, since the cast steel gating can be designed for gate removal by snapping rather than machine cutting. The preferred solution treatment is conducted at 2000-2200°F (1093-1204°C) for 1 to 4 hours followed by air cooling. Following the solution treatment, the alloy may be subjected to a strengthening treatment of 1400-1600°F (760-871°C) for up to 24 hours, but since the cast articles encounter temperatures in this temperature range during service, the strengthening treatment may be effected in situ during testing or initial service of the cast articles.

The primary strengthening mechanism of the stainless steel casting of the present invention, is believed to be by carbide dispersion in a solid solution strengthened matrix. Of the two types of carbides formed, i.e. MC and $M_{23}C_6$, MC carbide, where «M» is essentially Nb, (Nb), is relatively unaffected by solution treatment and hence remains as a strengthening constituent after solution treatment. The brittle $M_{23}C_6$ carbide constituent, (where «M» is essentially Cr) is spheroidized or partially dissolved during solution treatment. This dissolved carbide reprecipitates at the lower temperatures encountered during normal operating conditions and thus enhances the strength of the alloy in service. Thus the solution treatment redistributes, i.e. dissolves or spheroidizes the $M_{23}C_6$ carbide, the spheroidized or droplet form of the carbide being more ductile than the original angular form.

Sulphur is added to the stainless steel casting alloy of the present invention, in an amount of 0.2-0.4% to enhance machinability, and is combined with manganese or molybdenum as MnS or MoS. Silicon, which adds to the fluidity of the cast alloys, is normally present in commercial steels in an amount up to 2%, and 2.5-1.5% niobium is added for strengthening since niobium produces the very stable MC carbide. Tantalum may be similarly beneficial for strengthening but is more expensive than niobium.

Another advantage found in the use of the stainless steel alloys of the present invention is involved in the casting procedure. It has been found that the lower cost casting techniques as normally used for casting grey or ductile iron may be employed. Steel foundry casting methods are inherently more expensive than grey iron casting techniques, primarily because the metal is poured at higher temperatures, of the order of 3100°F (1704°C) in steel foundries, rather than 2600-2900°F (1427-1593°C) in iron foundries. It was found that the stainless steel of the present invention may be cast at tap temperature (the temperature at which steel is transferred to the pouring ladle) of about 2850°F (1566°C).

The gating practice used in steel foundries involving the use of additional gates, was used in the casting of the alloy of the present invention in order to obtain lower porosity and hence better quality castings. Because of the unique chemistry and microstructure of the stainless steel articles cast in accordance with the present invention, snap off gates may be used because of the presence of the brittle carbide constituent $M_{23}C_6$, which partially dissolves during the solution treatment. The presence of this carbide constituent in the as-cast condition permits removal of the

gates by snap-break separation, rather than the more expensive gate removal techniques involving machining operations, normally used for austenitic type steel castings.

The invention may be carried into practice in various ways and some preferred embodiments will now be illustrated in the following non-limiting examples, and with reference to the followings drawings, in which:-

Figure 1 is a photomicrograph (at 400X) of a metallographic specimen taken from a stainless steel turbocharger housing, cast in accordance with the present invention having the composition shown for DMS016 with 0.16%N,

Figure 2 is a photomicrograph similar to Figure 1 the composition including 0.20% N;

Figure 3 is a photomicrograph similar to Figure 1 the composing including 0.32% N;

Figure 4 is a photomicrograph similar to Figure 1 the composing including 0.35% N; and

Figure 5 is a simulated model of a turbocharger housing produced on a CAD (computer aided design) unit.

Examples

Turbine housings were prepared for testing in accordance with the present invention made of the DMS016 alloys shown in Table I and the resulting castings had the properties shown in Table II. Table I also shows the compositions of the closely related HC, HD and HK series alloys. The pouring temperature varied from 2733-2770° (1500-1521°C) for twelve (12) ladles poured in connection with the above example. The charge material was a commercial mixture approximating the desired chemistry of the DMS016 alloys in accordance with the invention.

Figure 1 is a 400X photomicrograph, showing the microstructure of alloy DMS016 modified with 0.16% N, at 400X showing approximately 10% austenite, which is the lighter phase, the darker phase being ferrite. The microstructure shown in Figure 2, (0.20%N) contains about 20% austenite, the microstructure shown in Figure 3 (0.32%N) contains about 40-50% austenite, and the microstructure shown in Figure 4 having 0.35% N contains about 50-55% austenite.

Table I

Element	Ni Resist® Type D5S ...	HD	HK	DMS 016A	DMS 016B	DMS 016 ¹	DMS 016 ²
C	1.5-2.3	0.5 max	0.2-0.6	0.1-0.2	0.19	0.16	0.24
Cr	1.6-2.2	26-30	24-28	28-32	29.65	28.39	30.94
Ni	34-38	4-7	18-22	4-8	5.47	5.21	5.33
Mn	0.7 max	1.5 max	2.0 max	1.0 max	0.67	0.49	0.65
Si	4.8-5.3	2.0 max	2.0 max	2.0 max	1.72	1.49	0.90
Mo	-	0.5 max	0.5	0.1 max	0.1 max	0.12	0.34
S	0.06 max	0.01 max	0.04 max	-	-	0.14	0.28
Nb	-	-	-	-	-	-	0.87
N	0.02	0.02	-	-	0.2	0.35	0.32
Fe	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.
% Ferrite	-	-	*	-	50**	40**	45**
% Austenite	-	-	-	-	50	60	55

* Basically austenitic with less than 10% Ferrite.

** Approximated from photomicrograph by line intercept estimation.

*** 0.035 - 0.09% Mg.

Table II

Properties	DMS 016A	DMS 016B	DMS 016 ¹	DMS 016 ²	DMS 016 ² *
Rm. temp. yield (x1000) psi	78.3 (55.1)	85.3 (60.0)	74.3 (52.2)	85.2 (59.9)	80.2 (56.4)
« « - Tensile (x 1000) psi	96.7 (68.0)	121 (85.1)	119.3 (83.9)	113.6 (79.9)	107 (75.2)
« « - % Elong.	18	24.4	26	6	5
17.50°F (954°C) (x 1000) psi	15 (10.5)	16.1 (11.3)	13.9 (9.77)	13.8 (9.70)	13 (9.14)
« « - Tensile (x 1000) psi	18.5 (13.0)	19.9 (14.0)	14.7 (10.3)	15.4 (10.8)	16.4 (11.5)
« « - % Elong.	27	37.8	22	28	22

* Properties after exposure to 1500°F (816°C) for 100 hours (substantially same properties exposure at 1750°F (954 °C) after 500 hours)

Figures in parentheses are the equivalent expressed in kg/m² × 10⁶.

A particular requirement for a turbocharger housing is that it must contain a wheel burst. The containment test is performed to determine whether the turbine housing of the particular alloy will contain a wheel which bursts as the rotating speed is increased in accordance with a particular containment requirement policy. Turbocharger manufacturers typically have several burst containment tests, i.e. for auto (gasoline), diesel and aircraft turbochargers. The first two tests are generally similar, while the latter (aircraft) may differ primarily in the use of a mechanically weakened wheel.

A test of the alloy designated DMS016², was run on a containment burst test stand. The shaft-wheel was modified to facilitate bursting, in accordance with standard aircraft test procedures, by drilling an axial hole in the hub and three holes in the back disc to obtain a three piece hub burst. The turbine inlet temperature was controlled to 1750°F (954°C) at the turbine inlet flange and the turbocharger was stabilised for 10 minutes at 97,500 rpm at 1750°F (954°C) turbine inlet temperature. The turbocharger was then rapidly accelerated until the weakened wheel burst at approximately 159,000 rpm. The housing was found to contain the wheel burst. The results of this test show that a turbocharger housing made of the material of the alloy, identified as DMS016², passes the same burst test as alloy the designated HK 30 plus Cb, which is the current austenitic alloy used for aircraft turbocharger housings.

A conventional aircraft turbine housing 10, as shown in Figure 5 was cast from the alloy of the present invention designated DMS016² and completed 600 hours of gas stand cyclic durability testing at an inlet temperature of 1750°F (954°C). Visual examination of the unit after completion of

600 hours of testing showed no cracks either at the tongue section 12, shown in Figure 5, or at the top of the volute (gas passage) surface. Hence, the cast housing made of alloy DMS016² was found to have excellent resistance to thermal cracking.

Oxidation testing at 1500°F (816°C) showed a weight loss of 0.03% after 100 hours. The sulphidation test at 1700°F (927°C) showed a weight loss of approximately 0.4% in one hour.

Thermal expansion measurements of the alloy of the present invention showed a linear expansion coefficient of $18.6 \times 10^{-6} \text{ } ^\circ\text{C}^{-1}$ ($10.1 \times 10^{-6} \text{ } ^\circ\text{F}^{-1}$) over the range of 300 - 1000°C. This expansion rate is similar to that of HK 30 stainless steel.

The turbocharger housing finite element thermal stress model shown in Figure 5 compared the standard NiResist material (D-5S) with a similar housing model constructed of the alloy DMS016², and the results shown in Table III, show that while DMS016² developed greater stress, it had a greater fatigue life. The temperature at the tongue 12 was 1520°F (827°C) and in the waste gate port region 16 was 1480°F (804°C). While these results were based on very limited creep data, the values for which may vary significantly, the data as shown in Table III indicates greater durability in the alloy of the present invention, DMS016².

The finite element stress analysis identified two distinct critical areas where fatigue cracks are expected to occur, namely the tongue 12 and the waste gate port region 16. Thus, it was found that DMS016² has higher strength at elevated temperatures than D5S (NiResist) and also has a higher modulus of elasticity and a slightly lower co-efficient of thermal expansion. The result is a casting able to withstand higher thermal stress.

Five samples of DMS016 with varying amounts of

Table III

Configuration	Location	Developed Stress (KSI)	Fatigue Life minimum (hours)	(Cycles) Typical
Base-line (D-5S Ni Resist)	Tongue	22.7 (16.0) *	160	370
	Wastegate port	8.8 (6.2)	880	1770
Base-line using DMS	Tongue	36.5 (27.7)	180	410
	wastegate	12.0 (8.44)	900	1820

Temperatures - 1520°F (827°C) at the tongue
1480°F (804°C) at the wastegate port region.

* Figures in parentheses are in $\text{kg/m}^2 \times 10^6$

nitrogen, were prepared and subjected to mechanical testing, the results of which are shown in Table IV. Since a minimum of about 7% of elongation is required for satisfactory ductility, these data indicate about 0.20% minimum nitrogen is required. The elongation data shown in Table IV also show cast samples of DMS016 alloy to be substantially devoid of the brittle sigma phase constituent in DMS016 alloys having a nitrogen content of 0.20% or more. The maximum solubility of N is about 0.6%. At 0.5%

N, brittle nitrogen compounds may appear, which will reduce ductility.

Based upon the experiments performed and the turbine housings exposed to a simulated or actual environment, the DMS016 alloy appears to meet the development guidelines that were established in that it has castability, machinability and service properties equal to or superior to D5S NiResist and in many areas approaches the properties of HK30 stainless steel, a more expensive high nickel material.

Table IV

N%	Yield strength (0.2% proof stress)	Ult. tensile Strength - Psi	Elongation Percent
0.14	88,500 (62.2)	95,200 (66.9)	3.0
0.14	91,900 (64.6)	97,000 (68.2)	2.0
0.16	90,100 (63.3)	96,400 (67.8)	3.0
0.16	88,600 (62.3)	97,600 (68.6)	3.0
0.20	90,000 (63.2)	105,800 (74.4)	7.0
0.20	86,200 (60.6)	103,200 (72.6)	9.0
0.32	80,200 (56.4)	114,800 (80.7)	11.0
0.32	78,200 (54.9)	113,100 (79.5)	14.0
0.35	86,200 (60.6)	120,800 (85.0)	13.0
0.35	81,200 (57.1)	119,600 (84.1)	14.0

Figures in parentheses are the equivalent expressed in $\text{kg/m}^2 \times 10^6$.

Claims

1. A cast stainless steel article having a duplex metallurgical structure of about 20 to 80% ferrite, the balance being austenite, and being substantially devoid of sigma phase the article comprising in weight percent:

27 to 31% chromium
4 to 6% nickel
0.2 to 0.5% nitrogen
0.2 to 0.4% carbon
0.5 to 1.5% niobium (columbium)
0.2 to 0.4% sulphur

and optionally

up to 2% silicon
up to 1.0% manganese
up to 1.0% molybdenum
up to 0.5% copper
up to 0.2% aluminium
up to 0.03% phosphorus

the balance being iron with incidental impurities.

2. An article as claimed in Claim 1 characterised by a nitrogen content of 0.3 - 0.4 weight percent.

3. An article as claimed in Claim 1 or Claim 2 characterised by a duplex structure of 40 - 60% ferrite, the balance being austenite.

4. An article as claimed in any preceding claim characterised by consisting by weight of 31% chromium, 5% nickel, 0.24% carbon, 0.65% manganese, 1% silicon, 0.35% molybdenum, 0.3% sulphur, 0.9% niobium, 0.32% nitrogen, the balance being iron.

5. An article as claimed in any preceding claim characterised by its having been solution treated for 1 to 4 hours at about 2000 to 2200°F (1093 - 1204°C).

6. An article as claimed in Claim 5 characterised by its having been air cooled from the solution treatment and subsequently subjected to a strengthening heat treatment at 1400 to 1600°F (760 - 871°C) for up to 24 hours.

7. A method for producing a cast stainless steel article having a duplex metallurgical structure of about 20 - 80% ferrite, the balance being austenite,

comprising the steps of: melting a commercial steel mixture to a target chemistry of in weight percent:

27 to 31% chromium
4 to 6% nickel
0.2 to 0.5% nitrogen
0.2 to 0.4% carbon
0.5 to 1.5% niobium (columbium)
0.2 to 0.4% sulphur

and optionally

up to 2% silicon
up to 1.0% manganese
up to 1.0% molybdenum
up to 0.5% copper
up to 0.2% aluminium
up to 0.03% phosphorus

the balance being iron with incidental impurities, heating the steel alloy mixture to a temperature of about 2850 - 2900°F (1566 - 1593°C) for a time sufficient to homogenise the melt; pouring the steel at a tap temperature of about 2850°F (1566°C) into moulds employing gates designed to minimise porosity; and allowing the article to solidify.

8. A method as claimed in Claim 7 characterised by subjecting the cast article to a solution treatment at about 2000 - 2200°F (1093 - 1204°C) for 1 - 4 hours or longer to redistribute $M_{23}C_6$ carbide (where «M» is essentially chromium).

9. A method as claimed in Claim 8 characterised by the step of removing the gates by snap breaking after the cast article has cooled to room temperature and before the solution treatment.

10. A method as claimed in Claim 8 or Claim 9 characterised in that the solution treated article is air cooled following the solution treatment.

11. A method as claimed in any of Claims 8 to 10 characterised in that the cast article is subjected to a strengthening treatment at about 1400 - 1600°F (760 - 817°C) for up to 24 hours.

Patentansprüche

1. Gegenstand aus nichtrostendem Gußstahl mit einem metallurgischen Doppelgefüge von etwa 20 -

80% Ferrit, Rest Austenit, bei dem eine Sigma-Phase im wesentlichen fehlt, bestehend aus (in Gewichtsprozent):

- 27 - 31% Chrom
- 4 - 6% Nickel
- 0,2 - 0,5% Sticks-ff
- 0,2 - 0,4% Kohlenstoff
- 0,5 - 1,5% Niobium (Kolumbium)
- 0,2 - 0,4% Schwefel

und wahlweise

- bis zu 2% Silizium
- bis zu 1,0% Mangan
- bis zu 1,0% Molybdän
- bis zu 0,5% Kbis zufer
- bis zu 0,2% Aluminium
- bis zu 0,03% Phosphor

der Rest Eisen mit zufälligen Verunreinigungen.

2. Gegenstand nach Anspruch 1, gekennzeichnet durch einen Stickstoffgehalt von 0,3 - 0,4 Gewichtsprozent.

3. Gegenstand nach Anspruch 1 oder 2, gekennzeichnet durch eine Doppelstruktur von 40 - 60% Ferrit, Rest Austenit.

4. Gegenstand nach einem der vorausgehenden Ansprüche, dadurch gekennzeichnet durch (in Gewichtsprozent) 31% Chrom, 5% Nickel, 0,24% Kohlenstoff, 0,65% Mangan, 1% Silizium, 0,35% Molybdän, 0,3% Schwefel, 0,9% Niobium, 0,32% Stickstoff, Rest Eisen.

5. Gegenstand nach einem der vorausgehenden Ansprüche, dadurch gekennzeichnet, daß er 1 bis 4 Stunden lang bei etwa 1093 - 1204 °C in Lösung behandelt worden ist.

6. Gegenstand nach Anspruch 5, dadurch gekennzeichnet, daß er nach der Lösungsbehandlung luftgekühlt und anschließend einer der Verfestigung dienenden, bis zu 24 Stunden andauernden Wärmebehandlung bei 760 - 871 °C unterzogen wird.

7. Verfahren zum Herstellen eines Gegenstandes aus nichtrostendem Gußstahl mit einer metallurgischen Doppelstruktur aus etwa 20 - 80% Ferrit, Rest Austenit, dadurch gekennzeichnet, daß ein kommerzielles Stahlgemisch in ein chemisches Material geschmolzen wird, dessen Zusammensetzung in Gewichtsprozent ist:

- 27 - 31% Chrom
- 4 - 6% Nickel
- 0,2 - 0,5% Sticks-ff
- 0,2 - 0,4% Kohlenstoff
- 0,5 - 1,5% Niobium (Kolumbium)
- 0,2 - 0,4% Schwefel

und wahlweise

- bis zu 2% Silizium
- bis zu 1,0% Mangan
- bis zu 1,0% Molybdän
- bis zu 0,5% Kbis zufer
- bis zu 0,2% Aluminium
- bis zu 0,3% Phosphor

der Rest Eisen mit zufälligen Verunreinigungen, daß das Stahlegierungsgemisch auf eine Temperatur von etwa 1566 - 1593 °C über eine Zeitdauer erhitzt wird, die ausreicht, um die Schmelze zu homogenisieren, daß der Stahl bei einer Anstichtemperatur

von etwa 1566 °C in Formen gegossen wird, wobei Ausgänge verwendet werden, die so ausgelegt sind, daß die Porosität ein Minimum wird, und daß sich der Gegenstand verfestigen kann.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß der Gußgegenstand einer Lösungsbehandlung bei etwa 1093 - 1204 °C über 1 bis 4 Stunden Zeitdauer oder länger unterzogen wird, um $M_{23}C_6$ -Karbit neu zu verteilen (wobei «M» im wesentlichen Chrom ist).

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß die Ausgänge durch Schnapp-Brechen entfernt werden, nachdem der Gußgegenstand auf Raumtemperatur abgekühlt ist, und bevor die Lösungsbehandlung durchgeführt wird.

10. Verfahren nach Anspruch 8 oder 9, dadurch gekennzeichnet, daß der durch Lösung behandelte Gegenstand im Anschluß an die Lösungsbehandlung luftgekühlt wird.

11. Verfahren nach einem der Ansprüche 8 bis 10, dadurch gekennzeichnet, daß der Gußgegenstand einer Verfestigungsbehandlung bei etwa 760 - 810 °C über eine Zeitdauer bis zu 24 Stunden unterzogen wird.

Revendications

1. Produit en acier inoxydable moulé possédant une structure métallurgique double à environ 20 à 80% de ferrite, le complément étant de l'austénite, et sensiblement exempte de phase sigma, ce produit comprenant en pourcentage en poids:

- 27 à 31% de chrome,
- 4 à 6% de nickel,
- 0,2 à 0,5% d'azote
- 0,2 à 0,4% de carbone,
- 0,5 à 1,5% de niobium (colombium),
- 0,2 à 0,4% de soufre

et éventuellement

- jusqu'à 2% de silicium,
- jusqu'à 1,0% de manganèse,
- jusqu'à 1,0% de molybdène,
- jusqu'à 0,5% de cuivre,
- jusqu'à 0,2% d'aluminium et
- jusqu'à 0,03% de phosphore,

le complément étant du fer comprenant des impuretés insignifiantes.

2. Produit suivant la revendication 1, caractérisé par une teneur en azote de 0,3 à 0,4% en poids.

3. Produit suivant l'une des revendications 1 et 2, caractérisé par une structure double à 40 à 60% de ferrite, le complément étant de l'austénite.

4. Produit suivant l'une quelconque des revendications précédentes, caractérisé en ce qu'il consiste, en poids, en 31% de chrome, 5% de nickel, 0,24% de carbone, 0,65% de manganèse, 1% de silicium, 0,35% de molybdène, 0,3% de soufre, 0,9% de niobium et 0,32% d'azote, le complément étant du fer.

5. Produit suivant l'une quelconque des revendications précédentes, caractérisé en ce qu'il a été soumis à un recuit de mise en solution pendant 1 à 4 heures à environ 2000 à 2200 °F (1093 à 1204 °C).

6. Produit suivant la revendication 5, caractérisé

en ce qu'il a été soumis à un refroidissement par air à la suite du recuit de mise en solution, puis soumis à un recuit de consolidation à 1400 à 1600°F (760 à 871°C) pendant jusqu'à 24 heures.

7. Procédé de production d'un produit en acier inoxydable moulé possédant une structure métallurgique double à environ 20 à 80% de ferrite, le complément étant de l'austénite, ce procédé consistant à élaborer, à l'état fondu, un mélange pour acier du commerce possédant une composition chimique prévue comprenant en pourcentage en poids:

27 à 31% de chrome,
4 à 6% de nickel,
0,2 à 0,5% d'azote
0,2 à 0,4% de carbone,
0,5 à 1,5% de niobium (colombium),
0,2 à 0,4% de soufre

et éventuellement

jusqu'à 2% de silicium,
jusqu'à 1,0% de manganèse,
jusqu'à 1,0% de molybdène,
jusqu'à 0,5% de cuivre,
jusqu'à 0,2% d'aluminium et
jusqu'à 0,03% de phosphore,

le complément étant du fer comprenant des impuretés insignifiantes, à porter la température du mélan-

ge d'acier allié à environ 2850 à 2900°F (1566 à 1593°C) pendant une période de temps suffisante pour réaliser l'homogénéisation de l'acier en fusion, à couler cet acier à une température de coulée d'environ 2850°F (1566°C) dans des moules utilisant des attaques conçues pour rendre la porosité minimale et à laisser le produit se solidifier.

8. Procédé suivant la revendication 7, caractérisé en ce qu'on soumet le produit moulé à un recuit de mise en solution à environ 2000 à 2200°F (1093 à 1204°C) pendant 1 à 4 heures ou plus longtemps, afin de redistribuer le carbure $M_{23}C_6$ (dans lequel «M» est essentiellement le chrome).

9. Procédé suivant la revendication 8, caractérisé en ce qu'il comporte l'opération consistant à séparer les carottes par rupture brusque une fois que le produit s'est refroidi jusqu'à la température ambiante et avant le recuit de mise en solution.

10. Procédé suivant l'une des revendications 8 et 9, caractérisé en ce que le produit ayant subi le recuit de mise en solution est soumis à un refroidissement par air à la suite de ce recuit de mise en solution.

11. Procédé suivant l'une quelconque des revendications 8 à 10, caractérisé en ce que le produit moulé est soumis à un recuit de consolidation à environ 1400 à 1600°F (760 à 871°C) pendant jusqu'à 24 heures.

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8

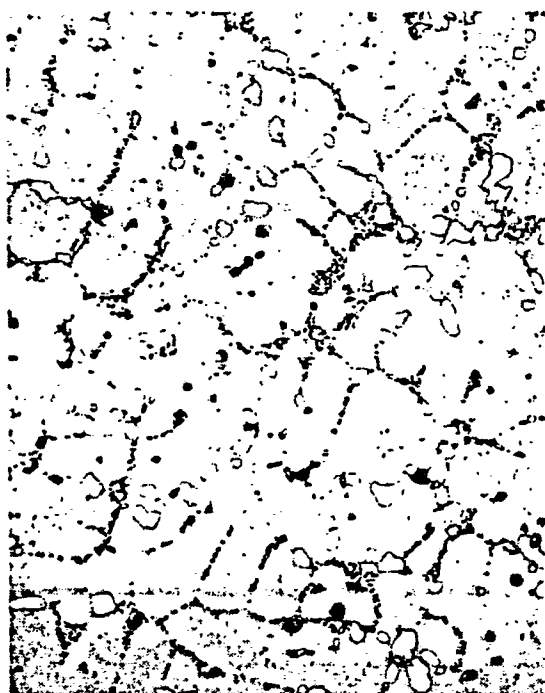


FIG. 1

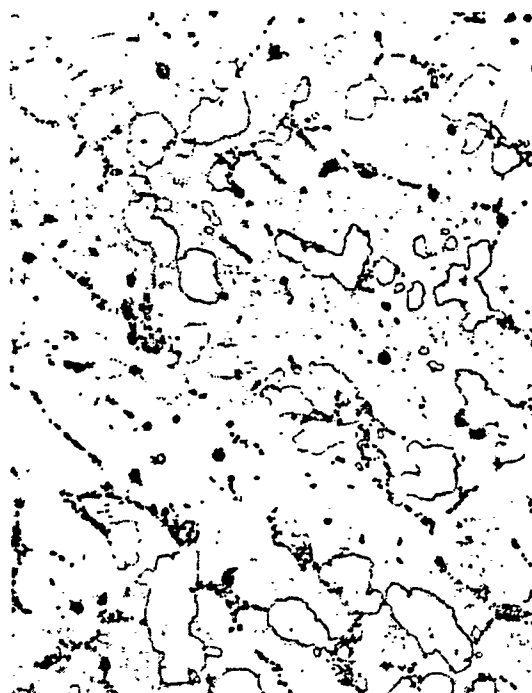


FIG. 2

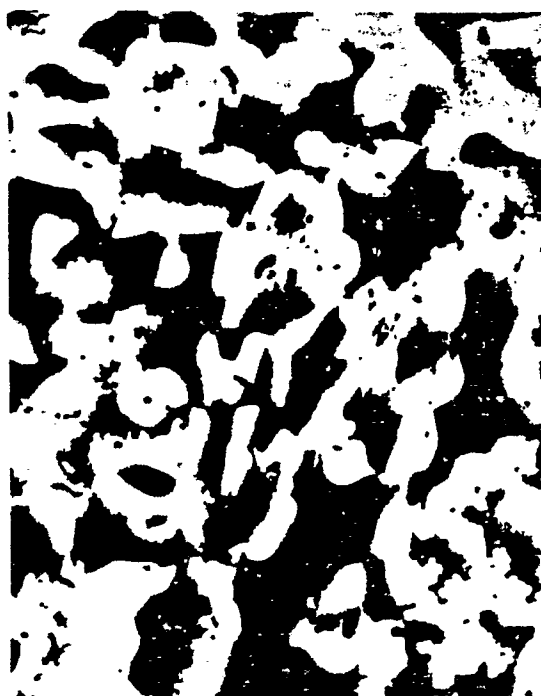


FIG. 3



FIG. 4

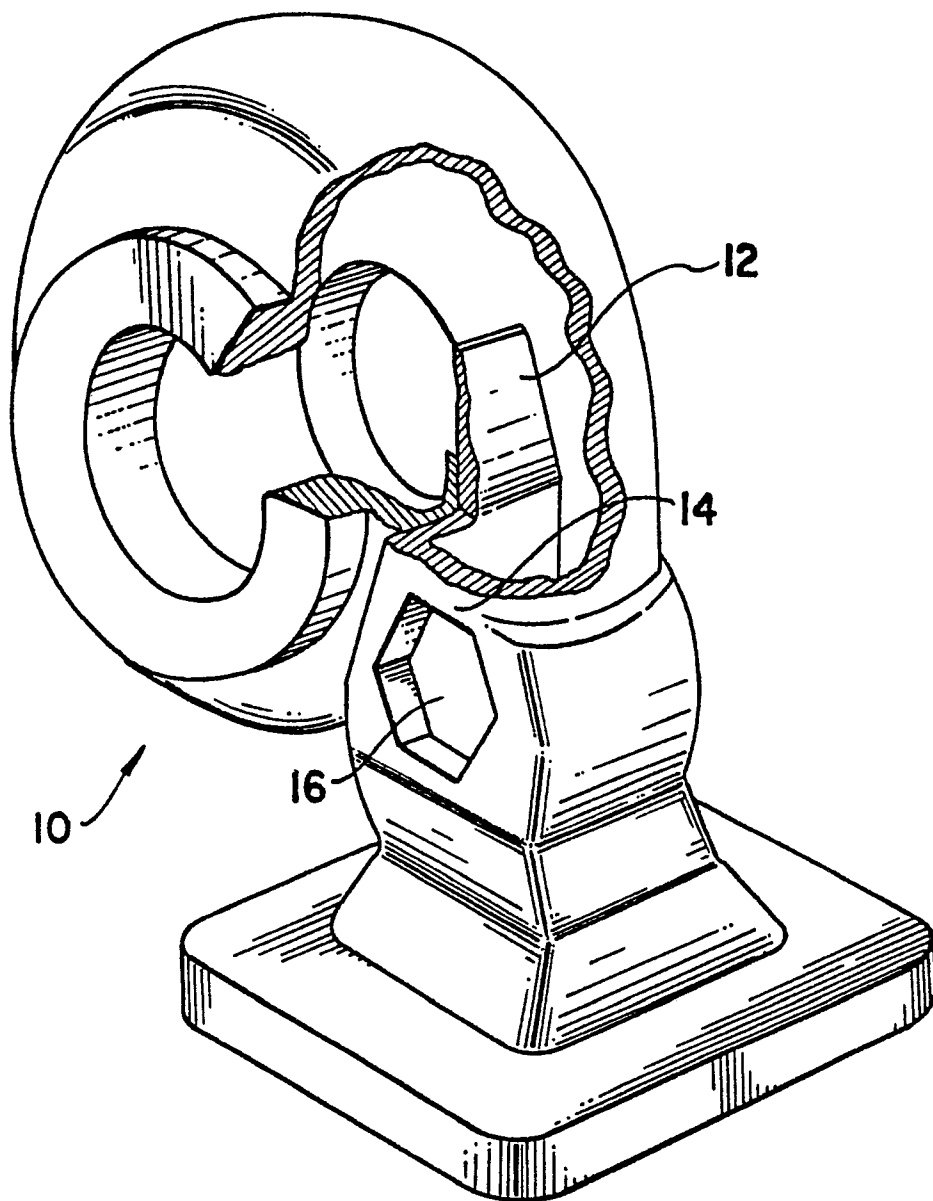


FIG. 5