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3,132,937
CAST STEEL

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The present invention relates to ferrous-base alloys and, more particularly, to cast ferrous-base alloys containing nickel.

It is well known that certain ferrous-base alloys, that is, alloys containing iron as their major constituent, can be produced with a martensitic matrix which can, by means of tempering and/or hardening heat treatments, provide in those alloys advantageous combinations of high strength, wear resistance, hardness, etc. Particularly advantageous wrought age-hardenable martensitic ferrous-base alloys have been disclosed in the Bieber U.S. patent application Serial No. 839,296 filed on September 11, 1959 (now U.S. Patent No. 3,093,518) and in the Decker et al. U.S. patent application Serial No. 80,381 filed on January 3, 1961 (now U.S. Patent No. 3,093,519). Among the alloys disclosed in the prior Bieber U.S. patent application Serial No. 839,296 are commercially available iron-base alloys containing, in percent by weight, about 18% to about 25% nickel, small interrelated amounts of carbon and columbium (niobium) and amounts of titanium and/or aluminum in the aggregate of at least about 1.5%. These wrought Bieber alloys can be subjected to an age-hardening heat treatment while in the martensitic condition to provide hitherto unattainable combinations of strength and ductility at room temperature and lower. The aforementioned Decker et al. U.S. application was concerned with wrought ferrous-base alloys containing about 10% to about 27% nickel together with interrelated amounts of cobalt and molybdenum which could also be age hardened while in the martensitic condition. The wrought alloys of both Bieber and Decker et al. are commercially available, have been widely publicized in metallurgical circles and are currently in the process of being tested for acceptance in many applications where strength coupled with toughness at ordinary temperatures is of paramount consideration. These wrought alloys, known as "maraging steels," are characterized on the whole by ease of formability both by hot-working and cold-working processes, by ease of weldability, through hardenability and by freedom from major distortion during hardening heat treatment.

Since the discovery of the remarkable combination of characteristics which can be provided in the wrought steels, considerable effort has been expended in an endeavor to provide a steel adapted to be employed in the cast and heat treated condition. It is well known that many structures of complex shape can be made more easily and cheaply by casting rather than by working methods. Accordingly, it is advantageous to provide a steel having ultra-high strength, toughness, ductility, through hardenability, dimensional stability, ease of weldability, etc., when in the condition resulting from casting and heat treatment without being mechanically worked. Although attempts were made to overcome the foregoing difficulties and provide a commercially acceptable cast steel suitable for use as ultra-high strength castings, none, as far as we are aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that by specifically controlling alloying elements including nickel, cobalt, molybdenum, titanium, and aluminum within special ranges of

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composition, a cast steel can be provided which exhibits in the cast and heat treated condition an advantageous combination of engineering characteristics.

It is an object of the present invention to provide a novel cast steel.

Another object of the invention is to provide a novel ferrous-base alloy suitable for use as castings.

The invention also contemplates providing a novel cast, thermally-homogenized steel.

An additional object of the present invention is to provide a novel process for producing ultra-high strength castings.

It is a further object of the invention to provide a novel cast structure made of a novel steel.

Other objects and advantages will become apparent from the following description.

Generally speaking, the present invention contemplates a cast, hardenable steel having a martensitic matrix and containing, in percent by weight, about 14% or even about 16% to about 17.5% nickel, about 8% to about 12% cobalt, about 4% to about 5% molybdenum, up to about 0.45% titanium, e.g., about 0.1% to about 0.45% titanium, about 0.05% to about 0.45% aluminum, small unavoidable amounts of carbon not exceeding about 0.05% and up to about 0.1% zirconium with the balance being essentially iron. The cast steel of the present invention usually contains residual and effective trace amounts of elements usually employed in finishing and/or deoxidation of maraging steel. Such elements include silicon, manganese, boron, calcium, rare earth elements (from the addition of mischmetal), lithium, magnesium, uranium, etc. Effective amounts of these elements include amounts up to about 0.2% silicon and up to about 0.2% manganese. The cast steel can also contain up to about 3.5% chromium with the chromium replacing nickel weight for weight and can contain small amounts of supplementary hardening elements such as tungsten, vanadium, columbium, tantalum, beryllium, copper, etc. The amounts of such supplementary hardening elements which can be employed to increase the strength of the cast steels of the present invention are inversely related to the amounts of cobalt and molybdenum. Acceptable maximum amounts of supplementary hardeners used singly when the cobalt and molybdenum contents are both at the low end of the respective ranges are about 0.45% vanadium, about 2% tungsten, about 0.5% columbium, about 0.5% tantalum, about 3% copper and about 0.3% beryllium. When employed in combination, lesser maximum amounts of the supplementary hardeners must be employed. It is to be understood that the expression "balance being essentially" contemplates the inclusion in the alloys of residual, contaminant and/or unavoidable amounts of impurities and/or incidental elements normally occurring in steel and/or normally associated with the aforementioned alloying elements.

The term "martensitic matrix" as employed herein refers to an alloy matrix which includes low temperature transformation products of austenite.

An optimum combination of cast alloy characteristics is obtained when the steel of the present invention contains about 16.0% to about 17.5% nickel, about 9.5% to about 11.5% cobalt, about 4.4% to about 5.0% molybdenum, about 0.10% to about 0.45% titanium, about 0.05% to about 0.45% aluminum, up to about 0.03% carbon, up to about 0.1% zirconium, with the balance being essentially iron. Impurities such as sulfur, phosphorus, nitrogen, oxygen, hydrogen, antimony, tin, selenium, tellurium, arsenic, and bismuth are advantageously kept at as low levels as commercially possible.

The cast steel of the present invention is produced by melting selected stock in air or under an inert atmosphere (including vacuum) in a melting furnace. Good results

are obtained when electrolytic nickel, Armco iron, electrolytic cobalt and ferro-molybdenum are melted in a high frequency induction furnace using an argon blanket. After the charge is molten, silico-manganese is added followed by aluminum, titanium, boron, zirconium and calcium. Of course, if the carbon content of the initial charge is too high, such can be reduced by the use of oxygen. After all alloying and deoxidation and/or desulfurization additions have been made to the molten alloy, the metal is cast at temperatures of about 2700° F. to about 3000° F. employing molds made of green sand, dry sand and other ceramic and/or metal materials. After the metal has solidified into a casting, it is stripped from the mold. During casting, known methods of refining grain size such as by employing stirring or vibration or by using inoculation procedures or by controlling pouring temperatures can be used with advantage. Following this, the casting is usually thermally (as opposed to mechanically) homogenized by heating for about four hours at 2100° F. With castings having large sections, it can be advantageous to extend the period of homogenization. On the other hand, it is desirable to avoid both overextending the homogenization time and varying the homogenization temperature more than about 50° F. in either direction, i.e., from about 2050° F. to about 2150° F. It can be advantageous to employ a protective atmosphere, e.g., argon, during homogenization. After the casting has been homogenized, it is cooled in air or more slowly to room temperature or at least to a temperature safely below the temperature required to transform the matrix thereof from austenite to martensite or a martensite-like phase. After the alloy has been transformed by cooling, the alloy is age hardened by heating for about on to about ten hours at a temperature of about 800° F. to about 1000° F. and, advantageously, or about three hours at 900° F. The age hardening heating is advantageously conducted in an oxidizing atmosphere, e.g., air, not only to induce strength characteristics in the alloy but also to provide a corrosion-resistant surface layer. Alternatively, protective coatings of substances such as nickel or cadmium can be used. After aging, it can be advantageous to bake the casting for a short period of time. It is typical of the preferred steels of the present invention that as cast they exhibit a hardness of about 30 to 34 Rockwell C units (Rc) and after age hardening, exhibit hardnesses of about 48 Rc to about 52 Rc.

For the purpose of giving those skilled in the art a better understanding of the invention, the following illustrative compositions in accordance with the present invention are set forth in Table I.

Table I

Alloy No.	Per-cent C	Per-cent Ni	Per-cent Mo	Per-cent Co	Per-cent Ti	Per-cent Al	Per-cent B	Per-cent Zr	Per-cent Fe ²
1.....	0.015	17.3	4.60	0.90	0.13	0.16	0.003	0.02	Bal.
2.....	0.023	16.0	4.60	0.70	0.26	0.08	0.003	0.02	Bal.
3.....	0.014	16.7	4.43	0.53	0.16	0.008	0.003	0.02	Bal.
4.....	0.014	16.8	4.48	11.20	0.17	0.092	0.003	0.02	Bal.
5.....	0.007	17.4	4.63	10.50	0.39	0.10	0.003	0.02	Bal.
6.....	0.006	17.3	4.6	11.4	0.27	0.03	0.003	0.02	Bal.
7.....	0.001	16.5	4.52	9.50	0.44	0.084	0.003	0.02	Bal.
8.....	0.012	16.9	4.79	10.60	0.38	0.090	0.003	0.02	Bal.
9.....	0.012	16.9	4.72	10.40	0.38	0.054	0.003	0.02	Bal.
10.....	0.018	16.9	4.53	10.45	0.38	0.066	0.003	0.02	Bal.
11.....	0.014	16.9	4.72	10.3	0.41	0.078	0.003	0.02	Bal.
12.....	0.02	17.4	4.45	11.3	0.26	0.058	-----	-----	Bal.

¹ Amounts added.

² Iron includes small amounts of silicon, manganese and/or calcium in amounts within the ranges set forth hereinbefore together with small amounts of impurities and incidental elements.

Cast steels within the present invention as set forth in Table I exhibit an advantageous combination of tensile characteristics such as yield strength (Y.S.) measured in thousands of pounds per square inch (K.S.I.), ultimate tensile strength (U.T.S.), Elongation (El.) measured in percent in one inch, reduction of area (R.A.) measured in percent and notch tensile strength (N.T.S.) together with

good impact resistance as measured in foot pounds (ft.-lbs.) in accordance with the Charpy V-Notch (C.V.N.) test conducted at room temperature. Illustrative values of tensile and impact characteristics measured on cast alloy specimens which were homogenized at 2100° F. for four hours, air cooled to room temperature, then age hardened for three hours at 900° F. and air cooled are set forth in Table II.

Table II

Alloy No.	0.2% Y.S. (K.S.I.)	U.T.S. (K.S.I.)	El., percent	R.A., percent	C.V.N., ft.-lbs.	N.T.S. ¹ (K.S.I.)
9.....	239.4	253.5	11.0	39.5	17.0	361.3
10.....	238.9	254.5	10.0	35.5	13.0	354.2
11.....	245.5	260.0	8.0	31.0	13.5	355.0

¹ Measured with a specimen having a 0.3 inch major diameter, 0.212 inch notch diameter and 0.0006 notch radius with a 60° included angle and a K_T value equal to 12.

The effect of raising the thermal homogenizing temperature to 2200° F. on elongation, reduction in area and impact resistance is shown in Table III.

Table III

Alloy No.	Homogenizing		U.T.S. (K.S.I.)	El., percent	R.A., percent	C.V.N., ft.-lbs.
	Time (hrs.)	Temperature, °F.				
9.....	4	2,100	253.5	11	39.5	17.0
	4	2,200	254.5	9	39.0	12.0
10.....	4	2,100	254.5	10.0	35.5	13.0
	4	2,200	256.5	8.0	27.5	14.5
11.....	4	2,100	260.0	8.0	31.0	13.5
	4	2,200	260.0	5.0	18.5	10.5

The effect of lowering the thermal homogenizing temperature and extending the treatment time on elongation, reduction in area and impact resistance is shown in Table IV.

Table IV

Alloy No.	Homogenizing		U.T.S. (K.S.I.)	El., percent	R.A., percent	C.V.N., ft.-lbs.
	Time (hrs.)	Temperature, °F.				
9.....	4	2,100	253.5	11.0	39.5	17.0
	8	1,800	250.5	9.0	39.5	12.5
10.....	4	2,100	254.5	10.0	35.5	13.0
	4	1,900	250.0	7.0	24.0	10.0
11.....	4	2,100	260.0	8.0	31.0	13.5
	8	1,900	257.0	5.0	13.5	8.5

Tables III and IV show that while optimum characteristics are obtained when steels of the present invention are thermally homogenized at about 2100° F. for four hours, other homogenizing treatments conducted at temperatures from about 1800° F. to about 2200° F. for up to about eight or even up to about sixteen hours can be employed without excessive sacrifice of properties.

It is to be noted that the ferrous-base alloys or steels of the present invention as defined hereinbefore fall within a broad class of cobalt-containing steels which, in general, are highly useful as wrought and hardened structures. When used as homogenized and hardened castings, however, cobalt-containing steels outside the present invention can exhibit low Charpy V-Notch impact values, e.g., below about 10 ft.-lbs., low percentages of elongation, e.g., below about 5%, and/or low tensile and yield strengths, e.g., below about 230 K.S.I.U.T.S. Steels as contemplated within the scope of the present invention are particularly suited for the production of castings and exhibit a high combination of characteristics required for ultra-high strength castings. Illustrative compositions falling within the broad class of cobalt-containing steel but outside the present invention are set forth in Table V.

Table V

Alloy	Percent C	Percent Ni	Percent Mo	Percent Co	Percent Ti	Percent Cb	Percent V	Percent Al	Percent Cu	Percent Fe ¹
A-----	0.028	16.0	4.55	6.57	0.24	-----	-----	0.10	-----	Bal.
B-----	0.017	17.3	4.55	7.02	0.14	0.15	-----	0.25	2.25	Bal.
C-----	0.023	15.8	4.65	6.75	0.36	0.16	-----	0.096	-----	Bal.
D-----	0.018	16.6	4.55	9.60	0.20	-----	0.49	0.30	2.05	Bal.
E-----	0.016	16.0	4.60	6.84	0.44	-----	0.47	0.25	-----	Bal.
F-----	0.024	16.1	4.68	6.80	0.20	0.19	0.49	0.26	-----	Bal.
G-----	0.018	16.1	4.60	9.56	0.20	0.22	0.50	0.12	-----	Bal.
H-----	0.014	16.2	4.65	6.70	0.38	0.17	0.51	0.095	2.10	Bal.
I-----	0.035	16.7	4.55	9.70	0.41	0.20	-----	0.11	2.05	Bal.
J-----	0.017	15.0	4.35	6.40	0.20	0.20	0.47	0.085	1.85	Bal.
K-----	0.012	16.6	4.43	7.60	0.29	-----	-----	0.14	-----	Bal.
L-----	0.018	17.4	4.50	14.1	0.17	-----	-----	0.10	-----	Bal.
M-----	0.019	17.8	4.38	10.6	0.19	-----	-----	0.087	-----	Bal.

¹ Iron includes small amounts of silicon, manganese, boron, zirconium and/or calcium together with small amounts of impurities and incidental elements.

Homogenized and age-hardened samples of alloys D to J uniformly exhibited Charpy V-Notch impact values below 10 ft.-lbs. Similarly treated samples of alloys B, L and M exhibited low percentages of elongations indicative of impaired ductility. Homogenized and age-hardened samples of alloys A, C and K exhibited comparatively low tensile and yield strengths.

In general, the use of columbium, vanadium and/or copper in the alloys of the present invention detrimentally affects the toughness of the alloy. Lowering the nickel content, the cobalt content and/or the molybdenum content below the aforementioned specified ranges causes alloys of the present invention to lose strength whereas raising the cobalt and/or molybdenum content above the specified ranges deleteriously affects the ductility of alloys of the present invention. Raising the nickel content above the specified range causes a loss of strength in the cast alloys of the present invention. Within the alloying range of alloys of the present invention set forth hereinbefore, an increase in the amount of aluminum and/or titanium increases the strength of the alloy. In particular, such increases of titanium improve the yield and tensile strengths of the alloy while at the same time improve the notch tensile strength and enhance the ductility of the alloy as measured in terms of percent elongation and percent reduction in area. However, raising aluminum and/or titanium above the ranges set forth hereinbefore leads to decreased ductility in the alloy.

Cast steels of the present invention are particularly advantageous when compared to other wrought steel compositions employed in the cast condition. A steel containing 18.5% nickel, 7% cobalt, 5% molybdenum, 0.4% titanium, 0.1% aluminum and 0.02% carbon together with small amounts of manganese, silicon, sulphur, phosphorus, boron, zirconium and calcium was cast, homogenized for four hours at 2100° F. and aged at 900° F. for three hours. As so treated, steels of this nominal composition exhibit low yield strengths and ultimate tensile strengths coupled with elongations below about 5%, reductions in area of about 12%, notch tensile strengths of the order of about 300 K.S.I. and Charpy V-Notch values below about 10 ft.-lbs. Thus, under the specified conditions of heat treatment, the wrought steel composition, when cast, exhibits a combination of mechanical characteristics including low ductility in combination with relatively low yield strength. This combination of mechanical characteristics is substantially poorer than the combination of characteristics exhibited by similarly treated alloys of the present invention particularly suited for use as ultra high strength castings.

The cast steels and/or ferrous-base alloys of the present invention are commercially advantageous in that they exhibit an outstanding combination of engineering characteristics when subjected to the relatively simple, quench-free heat treatment disclosed hereinbefore. After homogenization and transformation, the alloys of the present invention can be machined with ease to finish tolerances. Subsequent age hardening effects little dimensional change and does not induce severe strains and/or distortion in

the finish-machined casting. Other known ultra-high strength casting steels which require austenitizing, quenching and tempering heat treatments, are often difficultly through-hardenable in large sections as compared to the readily through-hardenable steels of the present invention. The required quenching treatment employed with known ultra-high strength casting steels induces severe stresses in machined castings resulting in a severe distortion problem in the final stages of manufacture of a cast and machined part or component. The stresses induced in a cast part made of known ultra-high strength cast steels by quenching, limit the commercial utility of said cast steels in the production of complex shapes having widely varying section sizes. Many proposed castings cannot be made from these known cast steels simply because quench induced stresses will cause cracks and other imperfections in the final product. In addition, the welding of such ultra-high strength cast steels usually presents considerable problems of preheat, post-heat, weld cracking and quench cracking. In the cast steels of the present invention simple aging at about 900° F. is sufficient to restore the strength characteristics to a weld-affected area. The nominal compositions of some known ultra-high strength cast steels are set forth in Table VI.

Table VI

Steel No.	Percent C	Percent Ni	Percent Cr	Percent Mo	Percent V	Percent Mn	Percent Si	Percent Al	Percent Fe ¹
A-A-----	0.35	1.8	0.80	0.38	-----	0.8	1.62	-----	Bal.
B-B-----	0.42	1.7	0.88	0.24	-----	1	1.18	-----	Bal.
C-C-----	0.38	1.7	0.45	0.27	-----	0.5	1.4	0.05	Bal.
D-D-----	0.40	0.55	0.50	0.20	-----	0.8	0.6	-----	Bal.
E-E-----	0.35	-----	5	1.5	0.4	0.3	1	-----	Bal.

¹ Iron includes small amounts of sulfur, phosphorus and other impurities.

After being austenitized (usually at a plurality of elevated temperatures), quenched and tempered in accordance with various recommendations of the originators and/or producers thereof, the known ultra-high strength cast alloys of Table VI exhibit combinations of tensile and impact characteristics as set forth in Table VII in comparison with the average characteristics of the steel of the present invention homogenized for four hours at 2100° F. and age hardened after martensitic transformation at 900° F. for three hours.

Table VII

Steel No.	0.2% Y.S. (K.S.I.)	U.T.S. (K.S.I.)	El. percent	R.A. percent	C.V.N., ft.-lbs.	N.T.S., U.T.S.
A-A-----	226.8	235.8	1.5	4.0	10.0	1.18
A-A-----	216-220	256-288	6-8	12.0	10.0	-----
B-B-----	247.0	290.0	8.6	20.3	10.4	-----
B-B-----	240.0	269.0	6.5	18.0	10.0	1.08
C-C-----	253.6	289.5	3.7	6.7	10.0	-----
D-D-----	230.0	285.0	4.5	-----	-----	-----
E-E-----	250.0	260.0	9.5	-----	-----	-----
Present steel	238-244	253-260	5-11	16-40	13-17	1.33-1.43

¹ At -40° F.

Where more than one set of properties is set forth for a particular steel, i.e., steel A—A and steel B—B, the properties were those exhibited after different heat treatments.

Table VII shows that the far more readily heat treatable steel of the present invention exhibits, on the average, a yield strength comparable to those of the known ultra-high strength cast steels, enhanced ductility as indicated by percent elongation and percent reduction in area, enhanced impact resistance as indicated by the Charpy V-Notch results and enhanced resistance to stress, resistance to crack initiation and resistance to crack propagation, in the presence of notches as indicated by the ratio of the notch tensile strength to the ultimate tensile strength, said notch tensile strength being measured on a tensile specimen having the same notch characteristics as set forth hereinbefore in reference to Table II.

Cast steels of the present invention can be employed as dies, cast armor, high speed impellers, aircraft castings, hydrospin blanks, gun parts, parts for heavy road equipment, tools, forming equipment such as rolls, etc. Because of the unique combination of characteristics exhibited by the cast steels of the present invention, the steel can be employed as cast components in situations where no other known cast steel can be employed. For example, by the use of the steels of the present invention, cast structures of heavy section can be produced having mechanical properties independent of the mass of the structure. The steels of the present invention can also be used in the wrought form. For example, a steel of the present invention similar to steel No. 11 which was hot rolled, annealed at 1500° F. for 1 hour and aged at 900° F. for three hours exhibited a yield strength of about 281 K.S.I., an ultimate tensile strength of about 285 K.S.I., an elongation of 11%, a reduction in area of 55%, a notch tensile strength of about 411 K.S.I. and a Charpy V-Notch value of about 14 ft.-lbs.

The cast steel compositions of the present invention are to be distinguished from prior known steel compositions which were particularly adapted to be employed in the wrought condition. It is well known that in many instances, casting provides a more economical and practical way to manufacture components of complicated design. The alloys of the present invention provide the art with an ultra-high strength, cast material having substantially the advantages of the known wrought steels together with additional advantages as discussed hereinbefore making them particularly adaptable for use in casting processes.

It is to be noted that with respect to alloy compositions set forth herein, percent (or %) indicates the amount of a given element in percent by weight of the alloy.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. An age-hardenable steel exhibiting particularly advantageous properties when employed as a thermally homogenized casting consisting essentially of, in percent by weight, about 14% to about 17.5% nickel, about 8% to about 12% cobalt, and 4% to about 5% molybdenum, up to about 0.45% titanium, about 0.05% to

about 0.45% aluminum, up to about 0.05% carbon, up to about 0.1% zirconium, up to about 0.45% vanadium, up to about 2% tungsten, up to about 0.5% columbium, up to about 0.5% tantalum, up to about 3% copper, up to about 0.3% beryllium with the balance being essentially iron, the amounts of said elements in the group consisting of vanadium, tungsten, columbium, tantalum, copper and beryllium being inversely related to the amounts of cobalt and molybdenum and being maintained such that the maximum specified amounts are employed only when the cobalt and molybdenum contents of the steel are near the low end of the specified range and when only one member of said group is present in the steel.

2. A cast structure made of the alloy as set forth and defined in claim 1.

3. A cast, thermally-homogenized age-hardenable steel consisting essentially of, in percent by weight, about 16% to about 17.5% nickel, about 9.5% to about 11.5% cobalt, about 4.4% to about 5.0% molybdenum, about 0.1% to about 0.45% titanium, about 0.05% to about 0.45% aluminum, carbon in unavoidable amounts up to about 0.03%, up to about 0.1% zirconium, with the balance being essentially iron.

4. A cast, thermally-homogenized steel consisting essentially of, in percent by weight, about 16% to about 17.5% nickel, about 9.5% to about 11.5% cobalt, about 4.4% to about 5.0% molybdenum, about 0.1% to about 0.45% titanium, about 0.05% to about 0.45% aluminum, carbon in unavoidable amounts up to about 0.03%, up to about 0.1% zirconium, with the balance being essentially iron, said cast steel being characterized by a Charpy V-Notch impact strength of at least about 13 foot-pounds combined with a ratio of notched to unnotched tensile strength of at least about 1.3 when in a condition resulting from homogenizing at about 2100° F. and thereafter aging after transformation for about 1 to about 10 hours at about 800° F. to about 1000° F.

5. An age-hardenable steel consisting essentially of in percent by weight, about 16% to about 17.5% nickel, about 9.5% to about 11.5% cobalt, about 4.4% to about 5.0% molybdenum, about 0.1% to about 0.45% titanium, about 0.05% to about 0.45% aluminum, up to about 0.03% carbon, up to about 0.1% zirconium, with the balance being essentially iron.

6. A process for producing an ultra-high strength cast structure comprising pouring a molten mass of ferrous-base alloy consisting essentially of about 14% to about 17.5% nickel, about 8% to about 12% cobalt, about 4% to about 5% molybdenum, about 0.05% to about 0.45% aluminum, up to about 0.45% titanium and up to about 0.05% carbon into a mold, freezing said mass of ferrous-base alloy under grain-refining conditions to form a cast structure, thermally homogenizing said cast structure at a temperature of about 2050° F. to about 2150° F., transforming the thus homogenized cast structure to provide therein a martensitic matrix and thereafter aging the transformed cast structure at a temperature of about 800° F. to about 1000° F. for about 1 to about 10 hours to harden and strengthen said matrix.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,132,937

May 12, 1964

Edward P. Sadowski et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 34, for "on" read -- one --; line 35, for "or" read -- for --; column 5, line 48, after "18.5%" strike out the comma; column 6, Table VII, under the heading "0.2% Y.S.(K.S.I.)", for "250.0" read -- 205.0 --; column 7, line 66, for "and" read -- about --.

Signed and sealed this 9th day of March 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

UNITED STATES PATENT OFFICE
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