

1

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**YTTRIUM CONTAINING FERROUS PRODUCTS
AND METHODS FOR PREPARING SAME**

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This invention relates to unique ferrous alloys possessing improved properties, and processes for preparing the same, and, more particularly, to cast iron containing small, but effective, amounts of yttrium.

It is known that the physical characteristics of ferrous metal containing carbon can be improved by forming the graphite in compacted, spheroidal, or nodular shapes. With the graphite in a compacted, or spheroidal, form, the metallic matrix is free of discontinuities, and possesses superior physical properties, particularly improved ductility.

Gray iron has been made more ductile by addition to the molten iron containing graphite-yielding carbon, certain agents, such as cerium, magnesium, calcium, misch metal, and the other materials, in the elemental form, as alloys, as mixtures with inert substances, or as chemical compounds of the desired addition metal.

There are certain disadvantages to each of the above identified addition agents, a few of which can briefly be mentioned as illustrative of the problems involved. Introducing elemental magnesium into molten ferrous metal is hazardous, since its boiling point, 1120° C., is below the melting point of a eutectic iron carbon solution, ordinarily maintained around 1500° C. The same disadvantage accompanies the introduction of elemental cerium, or calcium, since their respective boiling points are 1400° C. and 1170° C.

Introducing the foregoing addition agents into a ferrous melt as alloys with metals, or non-metals, or as mixtures with inert materials, has the disadvantage of not only adding sometimes unwanted ingredients to the iron, but also of requiring materials which in some instances are costly or are not readily obtainable.

In the preparation of malleable iron, white iron has been treated with certain inoculating agents in order to sensitize the casting for carbon precipitation during the heat treatment.

It is, therefore, an object of the present invention to provide an improved process for effecting the formation of spheroidal, compacted, or nodular, granules of graphite in cast ferrous metal containing carbon. It is still another object of the invention to improve the physical properties of cast iron. It is still another object of the invention to provide an addition agent that is efficient and effective, compared on a weight basis with previous addition agents, for the production of spheroidal carbon in iron. It is yet another object of the invention to provide a process for making spheroidal carbon iron using an addition agent which possesses a high vaporization temperature which improves the introduction into the ferrous metal. It is still another object of the invention to provide an addition agent for the manufacture of spheroidal carbon in iron which allows a high carbon

2

tolerance in the ferrous metal. It is a further object of the invention to provide an addition agent that increases the time period in which to cast the ferrous metal after addition to the ferrous melt. It is a still further object of the invention to provide an addition agent in which the nodulizing action can be better controlled. Other objects and advantages of the present invention will be apparent to those skilled in this field from a study of the following description.

Briefly stated, the invention is concerned with an iron casting containing from about 0.05% to about 0.8% by weight of yttrium, the balance a cast iron composition. The present invention also contemplates a process for manufacturing the above characterized ferrous metal containing carbon, by addition to the molten metal, a small, but effective, amount of yttrium.

The composition of the novel ferrous product of the invention, in the absence of yttrium, is that of cast iron, for example gray iron, or white iron. Generally, the product will contain at least 50% by weight iron and usually at least 90% by weight iron, carbon and silicon in the cast iron range, for example, 2% to 5% by weight of carbon and 1% to 5% by weight of silicon. The yttrium retained in the product of the invention is in the range from about 0.05% to about 0.8%, usually from about 0.2% to about 0.8% by weight.

The micro-structure in one form of product of the invention is obtained in the as-cast condition with spheroidal, compacted, or nodular graphite and substantially devoid of the flake form. The nodular, or spheroidal, form of carbon is obtained in any matrix which as-cast, without a nodulizing agent, possesses flake graphite, such as gray cast iron. The various matrix constituents and structure can be controlled by well known methods by regulating the ingredients with or without heat treatments to obtain, for instance, pearlite, ferrite, martensite, tempered martensite, acicular transformation product of austenite, or combinations of the foregoing.

The addition of yttrium also enhances what would otherwise be white iron, in another form of the invention. If heat treatments of the white iron are employed, beneficial results are obtainable which are attributable to yttrium. Also, the presence of yttrium in white iron improves its physical characteristics, in some instances.

In carrying out the process contemplated by the invention, yttrium is introduced into the molten cast iron. The yttrium may be added in its elemental form, as an alloy, or as a compound which, upon reaction, yields yttrium in effective amounts, by techniques previously known in this field. Because of the high melting and boiling points of yttrium, it can be added as an element with less danger than many other materials. However, some precaution need be taken so as to minimize the surface area of the addition agent, since the powdered form which has high exposed areas may cause the yttrium to react with explosive violence. For this reason, it may be desirable to introduce the yttrium in the form of a solid yttrium-containing agent, for example, 20% by weight yttrium—80% by weight silicon, or 20% by weight yttrium—45% by weight silicon—35% by weight iron alloys.

The amount of yttrium to be added to the bath will depend upon a number of conditions. If too large a quantity is retained in the product, iron carbide will

result in the as-cast structure. Too small amounts of yttrium will fail to obtain the optimum nodulizing effect of the carbon. The constituents in the melt, the temperature of the molten iron, the contemplated delay in casting after introduction of yttrium, the proportion of retained yttrium in the product, and the amount of retained yttrium desired will be factors to be considered. Addition amounts will, therefore, be such as to obtain in the cast metal retained yttrium in the proportions previously indicated.

In order to further illustrate the invention, the following examples are given which are not intended to limit the scope of the invention:

TABLE I

Chemical Analysis

Alloy No.	C	Si	Mn	S	P	Ni	Cr	Ti	Percent Y Retained
1	2.60	2.83	0.24	0.010	0.05	0.03	0.01	0.01	0.21
2	2.56	3.75	0.38	0.010	0.05	0.03	0.01	0.01	0.19
3	2.62	3.79	0.39	0.012	0.04	0.03	0.01	0.01	0.34
4	2.66	3.77	0.24	0.014	0.03	0.03	0.01	0.01	0.14
5	2.08	3.83	0.35	0.012	0.04	0.03	0.01	0.01	0.45
6	2.74	3.69	0.35	0.008	0.04	0.03	0.01	0.01	0.05
7	3.10	2.60	0.25	0.010	0.03	0.03	0.01	0.01	0.12
8	3.04	2.50	0.27	0.012	0.06	0.03	0.01	0.01	0.23
9	3.14	3.18	0.29	0.010	0.04	0.03	0.01	0.01	0.20
10	3.14	3.18	0.34	0.015	0.04	0.01	0.03	0.02	0.21
11	3.02	3.47	0.28	0.010	0.04	0.03	0.01	0.01	0.19
12	3.35	3.18	0.36	0.010	0.05	0.02	0.01	0.01	0.16
13	3.44	2.38	0.36	0.010	0.04	0.01	0.01	0.01	0.22
14	3.40	2.48	0.20	0.016	0.08	0.02	0.01	0.01	0.09
15	3.55	2.27	0.36	0.020	0.08	0.02	0.01	0.01	0.03
16	3.55	2.33	0.33	0.004	0.05	0.01	0.03	0.04	0.04
17	3.76	1.33	0.30	0.004	0.04	0.02	0.05	0.03	0.47
18	3.84	1.26	0.30	0.004	0.05	0.01	0.03	0.03	0.42
19	4.08	1.40	0.31	0.004	0.05	0.01	0.05	0.03	0.20
20	4.26	2.60	0.21	0.016	0.06	0.03	0.01	0.01	0.21
21	4.02	3.51	0.33	0.008	0.04	0.01	0.03	0.02	0.24
22	4.40	3.60	0.40	0.016	0.06	0.03	0.01	0.01	0.17

TABLE II

Treatment No.	Treatment
0	as cast.
1	1325° F.—5 hours—furnace cool to 1000° F.—air cool.
2	1750° F.—2 hours—furnace cool to 1325° F.—hold 20 hours furnace cool to 1000° F.—air cool.

TABLE III

Mechanical Properties Treatment No. 0

Alloy No.	Tensile Strength, p.s.i.	Yield Strength, p.s.i.	Elongation, Percent	Reduction of Area, Percent	Brinell Hardness No.
2	81,000	61,000	18.0	8.0	197
3	77,000	69,000	0.0	0.0	223
4	57,500	51,000	1.5	0.5	183
6	36,500	32,000	1.0	0.5	170
7	47,500		5.0	1.5	229
8	77,000	63,000	0.5	0	291
9	64,000	48,500	15.0	5.5	170
10	72,000	53,500	15.0	6.0	183
11	69,000	48,700	20.0	6.5	179
12	74,000	43,600	16.0	13.0	178
13	67,000	42,200	21.0	9.0	197
14	50,000	46,000	2.0	1.0	152
15	72,000	64,000	6.0	2.5	152
16	45,600	28,700	6.0	2.0	149
18	48,200	25,400	21.0	9.0	137
19	80,000	60,000	1.5	1.0	241
20	64,000	42,400	20.5	8.5	149
21	73,000	53,500	15.0	6.0	183
22	82,000	66,000	24.0	14.5	191

The foregoing tensile determinations are in accordance with ASTM requirements, A-339-55, "Standard Specification For Nodular Iron Castings."

TABLE IV

Mechanical Properties Treatment No. 1

Alloy No.	Tensile Strength, p.s.i.	Yield Strength, p.s.i.	Elongation, Percent	Reduction of Area, Percent	Brinell Hardness No.
2	80,000	60,500	20.0	8.0	187
9	69,000	49,500	26.0	11.5	170
10	72,000	53,500	20.5	7.0	197
11	70,000	49,100	22.5	9.5	174
12	66,600	36,500	18.5	15.0	142
13	63,000	42,000	20.5	9.0	149
20	65,000	44,000	23.5	9.5	156
21	72,500	53,500	15.0	7.5	197
22	78,000	58,400	16.0	6.5	178

The foregoing tensile determinations are in accordance with ASTM requirements, A-339-55, "Standard Specification For Nodular Iron Castings."

TABLE V

Mechanical Properties Treatment No. 2

Alloy No.	Tensile Strength, p.s.i.	Yield Strength, p.s.i.	Elongation, Percent	Reduction of Area, Percent	Brinell Hardness No.
1	63,000	45,700	19.5	9.0	156
3	73,000	59,500	10.0	4.0	163
4	52,300	49,600	7.0	4.0	167
5	74,000	61,300	10.0	4.0	134
7	50,000	36,400	10.0	3.5	193
8	55,000	45,000	12.0	4.0	144
14	40,000	28,300	6.0	3.0	137
15	39,000	29,000	7.5	3.0	137
16	37,100	22,700	11.0	4.0	121
17	48,000	25,600	20.5	8.5	121
18	48,200	25,400	21.0	9.0	137
19	47,300	24,500	23.5	11.0	121

The foregoing tensile determinations are in accordance with ASTM requirements, A-339-55, "Standard Specification For Nodular Iron Castings."

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We, therefore, particularly point out and distinctly claim as our invention:

We claim:

1. The process for producing iron castings in which graphitic carbon is present in the nodular form and with substantially no separation of flake-like graphitic carbon which comprises the steps of preparing a bath of molten cast iron mix, introducing into said bath a small but effective amount of yttrium sufficient to control occurrence of uncombined carbon as substantially spheroidal particles, and thereafter casting metal from said bath to produce a casting containing a small but effective amount of yttrium and containing graphite in a compacted form.

2. The process for producing iron castings in which graphitic carbon is present in the as-cast state as agglomerates of nodular form and with substantially no separation of flake-like graphitic carbon which comprises the steps of preparing a bath of molten cast iron mix, introducing into said bath yttrium in effective amounts ranging from about 0.2% to about 0.8% by weight, and thereafter casting metal from said bath to produce a casting containing a small but effective amount of yttrium and containing graphite in a compacted form.

3. The process of claim 2 wherein said cast iron mix contains from about 2% to about 5% by weight of carbon and from about 1% to about 5% by weight of silicon.

4. The iron casting comprising, from about 2% to about 5% by weight of carbon, from about 1% to about 5% by weight silicon, and from about 0.05% to about 0.8% by weight of yttrium.

5. An iron casting comprising about 0.05% to about

5

0.8% by weight yttrium, and the balance a cast iron composition characterized by uncombined carbon particles dispersed in the ferrous matrix in the spheroidal form.

6. An iron casting comprising about 0.05% to about 0.8% by weight yttrium, and the balance a gray cast iron composition characterized by uncombined carbon particles dispersed in the ferrous matrix in the spheroidal form.

7. An iron casting comprising about 0.05% to about 0.8% by weight yttrium, and the balance a white cast iron composition characterized by uncombined carbon particles dispersed in the ferrous matrix in the spheroidal form.

8. An iron casting comprising at least 90% by weight of iron, from about 0.05% to about 0.8% by weight yttrium, from about 1% to about 5% by weight of silicon,

6

said casting being characterized by uncombined carbon being in the spheroidal form.

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