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COMPOSITION AND METHOD FOR
TREATING CAST IRON

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The invention relates to the manufacture of cast iron, and provides both a new and useful method of making cast iron and new compositions of matter for use in such method.

Although research and invention have succeeded in broadening the usefulness and in improving the quality of cast iron, largely by providing a better understanding of cupola operation, proper selection of base mixtures, and correct employment of additions of such elements as chromium, nickel, and molybdenum, considerable difficulties in the founding of iron remain to be overcome.

Of these difficulties, the greatest is probably the sensitivity of cast iron to variations in wall thickness (or rate of cooling). For example, if a cast iron be selected that is gray throughout a one-quarter inch section, in a one or two inch section it will ordinarily be weak and open-grained and have a low resistance to wear. Conversely, if the percentages of carbon and silicon be adjusted to improve the physical properties in heavy sections, the cast iron will tend to chill to a white or mottled iron in the thinner sections, thereby tending to produce brittle, poorly machinable portions. In practice, strength and soundness in heavier sections are often sacrificed in order to insure machinability of the entire casting. Moreover, the sensitivity of cast iron to variations in wall thickness imposes limitations on the design of cast iron articles.

Of the methods heretofore proposed to ameliorate this condition, those most widely used are three in number. The first comprises the use of irons of different analysis for castings of different sections. One serious difficulty encountered in using this method is that of identifying the iron from a specific cupola charge and of drawing a clear dividing line between the products of successive cupola charges. The second method involves melting down in the cupola an iron of average or intermediate composition, and adjusting the percentages of silicon and carbon in individual ladles so as to produce irons suitable for sections of various thicknesses. This latter method is usually only approximate in its results, because of the difficulty of quickly and accurately estimating weights and compositions. The third method comprises the addition of small quantities of silicon or calcium silicide to a relatively low-silicon iron while the latter is in the ladle, just before pouring. This method has been widely adopted, despite the fact that it requires extremely accurate control of analysis and of melting conditions, largely because it affords greater latitude in the diversity of section sizes that may be cast from a single batch of cast iron.

It is an object of this invention to provide a method of treating cast iron while it is molten and preferably just before casting, for instance

in the ladle or in the cupola forehearth, to decrease its sensitivity to variations in rate of cooling or in wall thickness while maintaining or improving its strength, ductility, and resistance to wear. A further object is to provide novel compositions of matter suitable for use in the method of the invention.

In accordance with the invention, these objects are attained by adding to cast iron while it is molten, and preferably just before casting, a composition of matter comprising as its essential ingredients iron, silicon, and aluminum, to which is preferably added one or more of the metals calcium, zirconium, and manganese. The ingredients should be in intimate association, and are preferably alloyed with each other at least in part.

The silicon content may be between 25% and 85%, and is preferably between 60% and 80%. The iron should not exceed 65% and preferably does not exceed about 45%. The aluminum content may be between 0.25% and 10%, and is preferably between 0.5% and 6%. When calcium is present, it should be under 16%, e. g. between 0.5% and 15%, and is preferably between 1% and 5%. When zirconium is present, it should ordinarily be between 1% and 15%, and preferably between 3% and 10% although on occasion it may be as high as 25%. When manganese is present, it should ordinarily be between 1% and 15%, preferably between 3% and 10%, but may sometimes be as much as 25%. It is preferred that no one of the elements calcium, zirconium, or manganese be more than 25% of the total addition of silicon, calcium, zirconium, and manganese.

In general, the greater the number of ingredients, chosen from among those mentioned above, the better the quality of the cast iron. Thus, a preferred composition of the invention comprises 60% to 80% silicon, 1% to 4% aluminum, 1% to 4% calcium, 4% to 9% zirconium, 4% to 9% manganese, remainder iron.

A part, preferably less than half, of the calcium may be replaced by one or more of the metals barium, strontium, magnesium, and beryllium. Likewise, a part, preferably minor, of the zirconium may be replaced by one or more of the elements vanadium, uranium, columbium, tantalum, cerium, or thorium. Further, the zirconium may be either partly or wholly replaced by titanium.

Although the amount of the composition of the invention to be added to the molten cast iron will vary considerably, depending chiefly on the type of cast iron being treated, the analysis of the composition of matter added, and the properties desired in the final product, it will ordinarily be best to add enough to increase the

silicon content of the casting by from 0.05% to 1%, about 0.5% being of wide suitability.

In applying the method of the invention to standard foundry practice, it will usually be de-

Deflection (Defl.) is in inches on an 18-inch span. Depth of chill (Chill) is in inches. "B. H." signifies the Brinell hardness number of the surface of the arbitration bar sample.

TABLE A

No.	Introduced with ladle addition of silicon				Cast iron analysis		Properties of the cast iron				
	Percent Al	Percent Ca	Percent Zr	Percent Mn	Percent T. C.	Percent Si	Trans.	Defl.	Tens.	Chill	B. H.
1.....	•	•	•	•	3.1	1.8	2,100	0.17	33	1.1	212
2.....	•	0.05	•	•	3.0	1.9	2,150	0.24	37	1.0	217
3.....	0.04	•	•	•	3.1	1.8	2,950	0.37	42	0.25	212
4.....	0.10	0.04	•	•	3.1	1.8	2,950	0.31	45	0.30	217
5.....	0.02	•	0.10	•	3.0	1.9	2,900	0.34	45	0.43	217
6.....	0.03	•	•	0.06	3.0	1.9	2,500	0.32	45	0.38	217
7.....	0.03	0.04	0.04	•	3.1	1.8	2,600	0.30	43	0.10	217
8.....	0.03	0.03	0.07	0.08	3.1	1.9	2,500	0.29	45	0.09	207

sirable to reduce the silicon content of the cupola charge so that the ladle addition of the invention will bring the silicon percentage to the neighborhood of that usual in standard practice. But it will frequently be found advantageous to adjust the cupola charge and ladle addition to give a silicon content substantially higher than customary.

The relative effectiveness of various combinations of elements within this invention is illustrated by the data set forth in Table A. These data were obtained by preparing in the high frequency electric induction furnace, cast irons of accurately-controlled similar compositions. Just before casting each sample of iron, enough special addition alloy was used to add 0.75% silicon plus the indicated percentages of other elements, such as aluminum. The final cast iron in each case contained between 3.0% and 3.2% total carbon (T. C.) and between 1.8% and 1.9% silicon. The heats were cast into chill-depth test specimens, standard (A. S. T. M.) arbitration bars, tensile strength test samples, and step-bars. The transverse strength (Trans.) is given in pounds as determined at the center of an 18-inch span.

TABLE B.—Effects of ladle additions to cast iron

Alloy A=73.5% Si, 2.51% Al, 7.39% Mn, 2.76% Ca, 7.45% Zr, rest Fe.
Alloy B=76.0% Si, 2.84% Al, 7.28% Mn, 2.93% Ca, 6.86% Zr, rest Fe.
Alloy C=63% Si, 2.8% Al, 1.8% Ca, 5.8% Zr, 6% Mn, rest Fe.

Alloys used for ladle additions

No.	Percent Si	Percent Al	Percent Ca	Percent Zr	Percent Mn
1.....	97.9	•	•	•	•
2.....	Rest	•	5.7	•	•
3.....	49.8	11.7	•	•	•
4.....	84.8	8.4	4.3	•	•
5.....	81.6	2.8	•	10.1	•
6.....	85.1	3.0	•	•	•
7.....	81.9	3.1	5.3	5.0	9.4
8.....	76.0	2.9	2.8	6.9	7.3

*None. **None, or negligible.

The type of improvement in the properties of cast iron afforded by the invention, as compared with the effects of ladle additions of ferrosilicon and calcium-silicon, respectively, is indicated in Table B, which contains data obtained under commercial foundry conditions. All tests reported in each of the groups I to III of Table B were made on the same iron, produced in the same cupola charge, and with all conditions, other than the material added to the ladle, kept constant. The abbreviations used in Table B have the same meaning as the corresponding abbreviations in Table A.

Kind of ladle addition	Analysis of cast iron produced				Properties of cast iron produced				
	Percent T. C.	Percent C. C.*	Percent Si	Percent Mn	Trans.	Defl.	Tens.	Chill	B. H.
GROUP I.—0.25% Si ADDED TO LADLE									
75% Fe-Si.....	3.6	0.72	1.8	0.82	2,650	0.29	35	0.08	192
Ca-Si I.....	3.5	0.85	1.6	0.74	3,100	0.34	39	0.13	207
Alloy A.....	3.6	0.88	1.8	0.96	3,150	0.36	35	0.03	187
GROUP II.—0.5% Si ADDED TO LADLE									
50% Fe-Si.....	2.7	0.86	1.6	0.32	3,300	0.31	44	0.56	228
Ca-Si I.....	2.6	0.63	1.9	0.39	3,400	0.29	51	0.25	223
Alloy A.....	2.7	0.58	1.9	0.48	3,900	0.52	49	0.19	207
GROUP III.—0.75% Si ADDED TO LADLE									
60% Fe-Si.....	3.0	0.64	1.6	0.38	2,400	0.24	41	0.37	217
Ca-Si II.....	3.0	0.98	1.2	0.38	2,800	0.26	47	1.00	241
Alloy B.....	3.0	0.65	1.4	0.42	2,800	0.34	43	0.25	217
Alloy C.....	3.1	0.70	1.5	0.43	3,100	0.34	51	0.37	217

*C. C.=combined carbon.

The invention is applicable not only to plain cast irons but also to cast irons containing the customary alloyed additions such as chromium, molybdenum, and nickel. When used in this connection, it will often be advantageous to add one or more of these elements in admixture, or alloyed, with the composition of matter of this invention. In such instances, the added element should replace part of the silicon or iron rather than of the ingredients manganese, calcium, zirconium, and aluminum. Chromium and molybdenum tend to increase the sensitivity of cast iron to variations in rate of cooling. This tendency may be to a great extent offset by applying the principles of this invention, thereby further extending the usefulness of chromium and molybdenum additions in cast iron.

I claim:

1. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto a small amount, sufficient to increase the silicon content thereof by at least 0.05%, of a composition of matter containing about 0.5% to 10% aluminum, 0.5% to 15% calcium, remainder principally iron and silicon, the iron content being less than 65%, the silicon content being at least 25%.

2. In the method of making cast iron castings which comprises producing in the cupola an iron containing less silicon than is desired in the casting, and adding ferro-silicon to such iron just before casting, the improvement which comprises adding to the iron, simultaneously with the addition of ferro-silicon and in intimate association therewith, at least 0.25% aluminum and at least 0.50% calcium, each in an amount not over about 25% of the total addition of silicon, aluminum, and calcium, such simultaneous additions of ferrosilicon, aluminum, and calcium serving to decrease the sensitivity of the said iron to variations in rate of cooling.

3. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto an amount, sufficient to increase the silicon content thereof by between about 0.05% and about 1%, of a composition of matter containing between 25% and 85% silicon, 1% and 10% aluminum, 1% and 15% calcium, remainder principally iron, the iron content being less than 65%.

4. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto a small amount, sufficient to increase the silicon content thereof by at least 0.05%, of a composition of matter containing as essential ingredients silicon, iron, aluminum, calcium, and zirconium, the iron content being less than 45%, the calcium content being at least 0.5% but under 16%, the aluminum content being between 0.25% and 10%, the zirconium content being between 1% and 15% and the silicon content being greater than that of any of the ingredients iron, aluminum, calcium, and zirconium.

5. In the method of making cast iron castings which comprises producing in the cupola an iron containing less silicon than is desired in the casting, and adding ferro-silicon to such iron just before casting, the improvement which comprises adding to the iron, simultaneously with the addition of ferro-silicon and in intimate association therewith, between 0.25% and 10% aluminum, between 0.5% and 15% calcium and between 1% and 15% zirconium, each in an

amount not over about 25% of the total addition of silicon, aluminum, calcium and zirconium, such simultaneous additions of ferrosilicon, aluminum, calcium, and zirconium serving to decrease the sensitivity of the said iron to variations in rate of cooling.

6. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto an amount, sufficient to increase the silicon content thereof by between about 0.05% and about 1%, of a composition of matter containing between 25% and 85% silicon, 0.5% and 10% aluminum, 0.5% and 15% calcium, 1% and 15% zirconium, remainder principally iron, the iron content being less than 65%.

7. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto a small amount, sufficient to increase the silicon content thereof by at least 0.05%, of a composition of matter containing as essential ingredients silicon, iron, aluminum, calcium, zirconium, and manganese, the iron content being less than 45%, the aluminum content being between 0.25% and 10%, the calcium content being between 0.5% and 15%, the zirconium content being between 1% and 15%, the manganese content being between 1% and 15% and the silicon content being greater than that of any of the ingredients iron, aluminum, calcium, zirconium, and manganese.

8. In the method of making cast iron castings which comprises producing in the cupola an iron containing less silicon than is desired in the casting, and adding ferro-silicon to such iron just before casting, the improvement which comprises adding to the iron, simultaneously with the addition of ferro-silicon and in intimate association therewith, between 0.25% and 10% aluminum, between 0.5% and 15% calcium, between 1% and 15% zirconium and between 1% and 15% manganese, each in an amount not over about 25% of the total addition of silicon, aluminum, calcium, zirconium and manganese, such simultaneous additions of ferrosilicon, aluminum, calcium, zirconium, and manganese serving to decrease the sensitivity of the said iron to variations in rate of cooling.

9. Method of treating molten cast iron, to decrease its sensitivity to variations in rate of cooling, which comprises adding thereto an amount, sufficient to increase the silicon content thereof by between about 0.05% and about 1%, of a composition of matter containing between 25% and 85% silicon, 0.5% and 10% aluminum, 0.5% and 15% calcium, 1% and 15% zirconium, 1% and 15% manganese, remainder principally iron, the iron content being less than 65%.

10. Method as defined in claim 9, wherein the said composition of matter contains 60% to 80% silicon, 1% to 5% aluminum, 1% to 6% calcium, 3% to 10% zirconium, 3% to 10% manganese, remainder iron.

11. A composition of matter comprising 0.5% to 10% aluminum, 0.5% to 10% calcium, remainder iron and silicon, the iron being less than 65%, the silicon being at least 25%; said composition of matter being further characterized in that when it is added to molten cast iron in amounts sufficient to increase the silicon content thereof by between about 0.05% and 1% it materially decreases the sensitivity of the cast iron to variations in the rate of cooling.

12. A composition of matter comprising 0.5%

to 10% aluminum, 0.5% to 10% calcium, 1% to 25% manganese, remainder iron and silicon, the iron being less than 65%.

13. A composition of matter comprising 1% to 5% aluminum, 1% to 6% calcium, remainder iron and silicon, the iron being less than 45%.

14. A composition of matter comprising 1% to 5% aluminum, 1% to 6% calcium, 60% to 80% silicon, remainder iron.

15. A composition of matter comprising 0.5% 10

to 10% aluminum, 0.5% to 10% calcium, 1% to 25% zirconium, 1% to 25% manganese, remainder iron and silicon, the iron being less than 65%.

16. A composition of matter comprising 1% to 5% aluminum, 1% to 6% calcium, 3% to 10% zirconium, 3% to 10% manganese, 60% to 80% silicon, remainder iron.

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