On the Structural Diagram of Cast Iron

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On the Structural Diagram of Cast Iron*

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Synopsis

The method for expressing the structural diagram of cast iron was studied and a new standard diagram was determined. From this diagram, we can know (1) the ranges of structure of cast iron with various components and sectional sizes, (2) a stable range of pearlitic structure and (3) the difference between the effect of carbon and that of silicon on the structure.

Comparing the results with Greiner-Klingenstein's and Sipp's data, the writer made clear that the total sum of carbon and silicon (C + Si) and the saturation degree of carbon (Sc) are undesirable as the unit to express carbon and silicon contents in the structural diagram of cast iron.

I. Introduction

Cooling rate which depends upon a sectional size of iron cast has a great effect on the structure of cast iron. It is technically difficult to control cooling rate as freely as the founding conditions and compositions. In the structural diagram many considerations should, therefore, be given to the effect of a sectional size.

From this point of view, the most famous Maurer's diagram(1) is very unsatisfactory. Against it, this point was considered in Greiner-Klingenstein's(2) and Sipp's(3) diagrams. However, they also have many questions on using the total sum of carbon and silicon (C + Si) or the saturation degree of carbon (Sc) as the unit to express carbon and silicon contents.

Hence, the writer studied the method most applicable to expressing the structural diagram of cast iron and determined a new standard diagram.

II. New method for expressing structural diagram of cast iron

A new structural diagram of cast iron is shown in Fig. 1. It is drawn from Sipp's data and is the combination of two diagrams of cast irons containing 1.5% and 2.5% Si, showing the relations between carbon content, cooling rate (sectional size) and the structure. In the diagram, I, II and III show cementitic, pearlitic and ferritic structures respectively.

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(1) E. Maurer und P. Holtzhausen, Stahl und Eisen., 47 (1927), 1805, 1977.

(2) F. Greiner und Th. Klingenstein, Stahl und Eisen., 45 (1925), 1173 ; Z. V. d. I (1926), 388.

(3) Sipp, Archiv. für das Eisenhüttenwes., 12 (1940), 207.

The characteristics of this diagram are as follows:

(a) A careful consideration is given to the effect of sectional size on the structure.

(b) As the unit to express carbon and silicon contents, each absolute value is used. This diagram is, therefore, reasonable and convenient for practical use.

(c) The ranges of structure of cast iron containing various amount of silicon are easily found. For instance, the range of the structure of cast iron containing 2.0 % Si may be found by drawing a line (a dotted line in Fig. 1) in the middle of 1.5 % and 2.5 % lines. Other ones are found in the same manner.

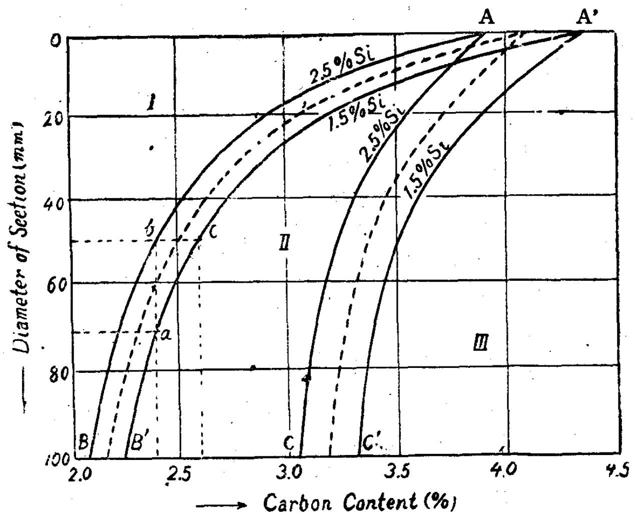

Fig. 1 New structural diagram of cast iron (by Sipp's data)

(d) The range enclosed by the lines A′B′ and AC is a stable one of pearlitic structure. Castings in this range always have pearlitic structures in spite of some variations in carbon and silicon contents and in cooling rate·

(e) The effects of carbon and silicon on the structure can be compared. When a casting of 49 mm section contains 2.4 % C and 1.5 % Si, it corresponds to the point b in the diagram and is white or mottled iron. In such a composition, the limit of section for pearlitic structure is at the point a, which is of 71 mm section. To change the structure of the casting into the pearlitic one by varying the content of silicon, while that of carbon remains the same, the point a should be brought, at least, to the point b corresponding to 2.5 % Si. On the other hand, to do so by varying the carbon content alone, the point a should be brought to the point c corresponding to 2.6 % C. In consequence, in this case the addition of 1 % Si may have the same effect on the structure as that of 0.2 % C.

As above described, this method has many advantages, but Sipp's data used here are not reliable. Therefore, the writer made many experiments and determined a new standard structural diagram by the method explained below.

III. Experimental method

Castings were made of meterials charged whose composition is shown in Table 1. Kamaishi No.3 pig, white pig and Hôkoku iron were used as base materials and Cleveland pig and metallic silicon were charged to control phosphorus and silicon contents respectively. These metals were melt in Kryptol furnace and cast in a dry sand mould. The casting and the maximum heating temperature were 1400° and 1500°C respectively. Conical ingots of 780 mm axial length and 2−40 mm cross section were obtained. They were cut along the axis at every 2 cm distance. The structure of section of each piece was observed under a microscope and limits of section for each structure were measured. The composition of each ingot is shown in Table 2. A new standard structural diagram was determined with the data thus obtained,

Table 1. Composition of materials charged

Material	C, %	Si, %	Mn, %	P, %	S, %
Kamaishi No. 3pig	4.01	1.55	0.93	0.306	0.039
White pig	4.31	0.002	0.019	neg	0.035
Cleveland pig	3.51	2.93	0.62	1.74	0.026
Hôkoku iron	<0.1	—	—	—	—

Table 2. Composition of cast irons

No.	C, %	Si, %	Mn, %	P, %	S, %
A 1	2.20	1.46	0.61	0.233	0.025
A 2	2.42	1.42	0.65	0.254	0.022
A 3	2.57	1.41	0.55	0.244	0.029
A 4	2.81	1.60	0.45	0.255	0.044
A 5	2.96	1.54	0.79	0.332	0.019
A 6	3.16	1.40	0.62	0.435	0.025
A 7	3.36	1.59	0.45	0.227	0.039
A 8	3.45	1.47	0.71	0.356	0.033
A 9	3.62	1.57	0.53	0.323	0.030
A10	3.79	1.48	0.67	0.229	0.027
B 1	2.30	2.41	0.58	0.375	0.031
B 2	2.51	2.53	0.63	0.380	0.021
B 3	2.62	2.47	0.63	0.421	0.029
B 4	2.73	2.51	0.64	0.362	0.029
B 5	2.80	2.39	0.64	0.426	0.023
B 6	3.00	2.48	0.64	0.351	0.024
B 7	3.15	2.46	0.71	0.216	0.037
B 8	3.38	2.48	0.75	0.384	0.032
B 9	3.58	2.33	0.51	0.196	0.037
B10	3.76	2.47	0.74	0.416	0.028

IV. Experimental results and disucussion

Fig. 2 shows the diagram of cast iron in which silicon content is prescribed at 1.5%. In the Fig., I, IIa, II and IIb are the ranges of white, mottled, pearlitic and ferritic irons respectively. The case in which silicon content is prescribed at 2.5% is shown in Fig. 3. In this diagram, except the line A, the lines B and D are considerably shifted to smaller sections as compared with those in Fig. 2, and irons are softened. Here, an attention should be paid to the fact that the range II is not a perfect pearlitic structure, but that the range between the line B and the dotted line C contains considerably eutectic structure and irons are very softened. True pearlitic structure is limited in a very narrow range between the lines C and D.

To investigate Greiner-Klingenstein's diagram, the data obtained were laid on that diagram as shown in Fig. 4. For reference, Sipp's data were also laid on it. A boundary line between white and mottled irons was abridged in all data to prevent a complexity. From the diagram, it is, first of all, clear that, with variation of carbon and silicon contents, even though (C + Si) remains the same, the ranges of structure slip out. It is, therefore, undesirable to use (C + Si) as the unit to express carbon and silicon contents in the structural diagram.

When (C + Si) is high, the data obtained are comparable to Greiner-Klingentein's data, but, as (C + Si) decreases, the former slips out of the latter.

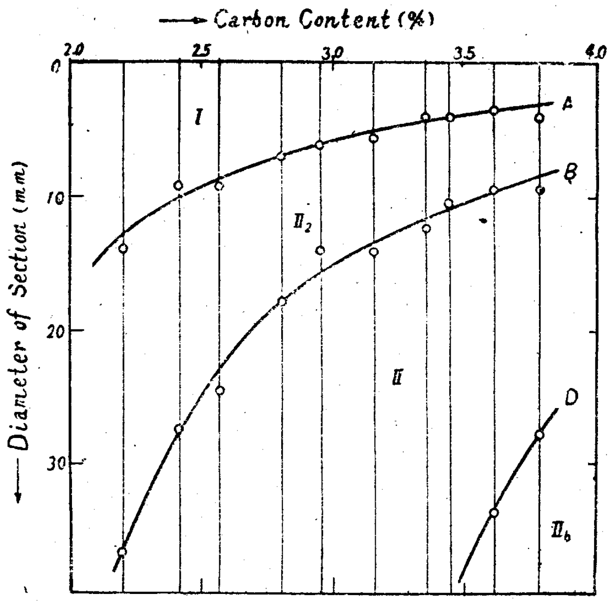

Fig. 2 Structural diagram of cast iron containing 1.5 % Si.

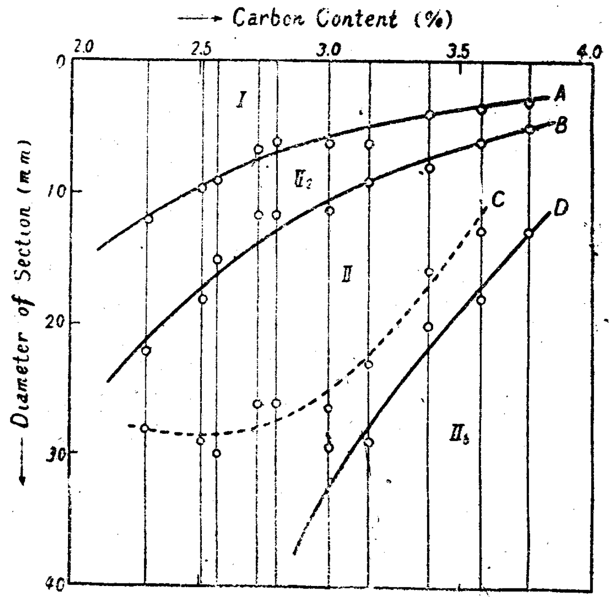

Fig. 3 Structural diagram of cast iron containing 2.5 % Si.

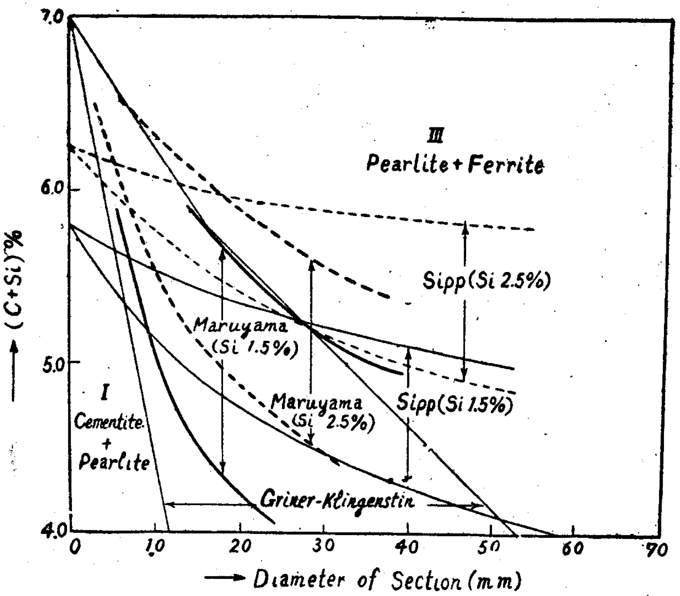

Fig. 4

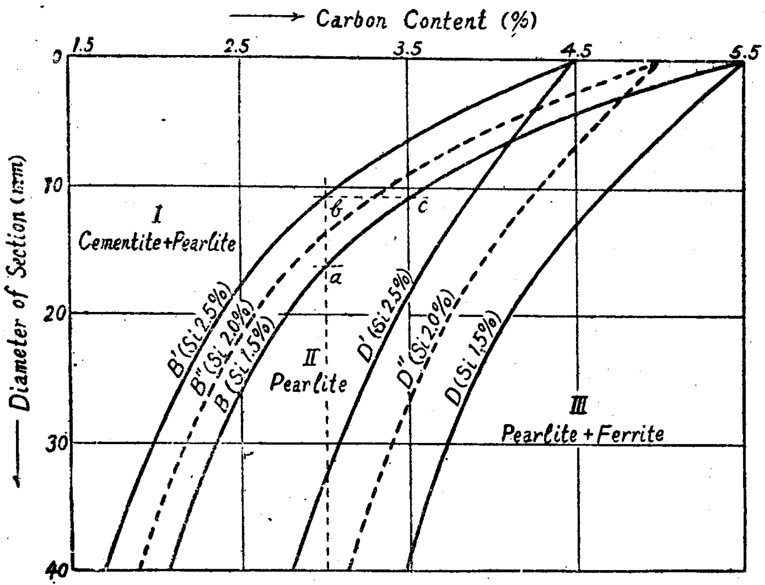

Fig. 5 New standard structural diagram of cast iron.

On the other hand, both data gradually approach each other as the silicon content decreases. Sipp's data considerably differ from the both.

When each line obtained is extrapolated to smaller section, they have a tendency to converge on the point of 7.0% (C + Si), at the size of 0 mm. Applying this tendency to each line in Fig. 2 and 3 and combining them, a new simple standard structural diagram of cast iron shown in Fig. 5 may be obtained. In the diagram, lines of 1.5% Si converge on the point, $c = 7.0 - 1.5 = 5.5$ (%), and lines of 2.5% Si on the point, $c = 7.0 - 2.5 = 4.5$ (%). This new diagram has various characteristics as already mentioned.

To investigate Sipp's diagram, the data obtained has been laid on it as shown in Fig. 6. From the diagram, it is clear that, with variation of carbon and silicon contents, even though Sc remains the same, the structure considerably slip out. It is, therefore, undesirable to use Sc as the unit to express carbon and silicon contents in the structural diagram.

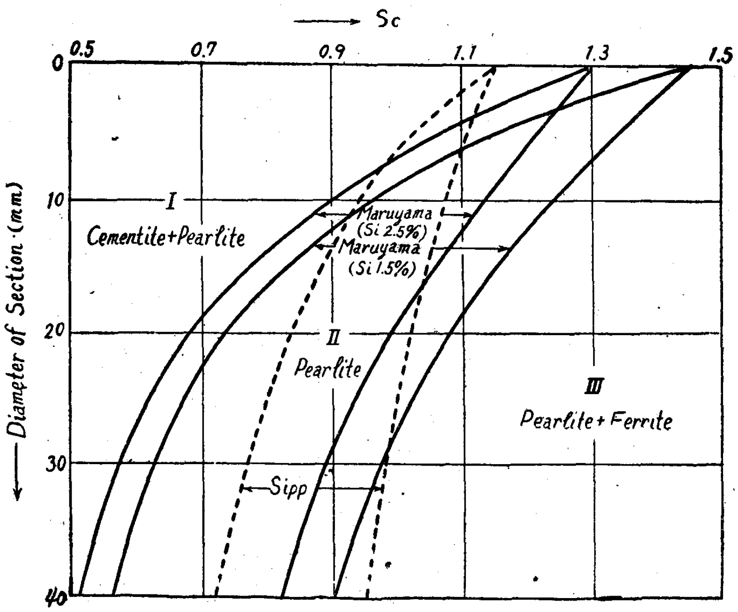

Fig. 6

Summary

A new standard structural diagram of cast iron was determined, which is the combination of two diagrams of cast irons containing 1.5 % and 2.5 % Si, showing the relations between carbon content, cooling rate and the structure. In the diagram, every boundary line of the structure converges on the point of 7.0 % (C + Si), at the size of 0 mm.

The characteristics of this diagram are as follows:

(a) A careful consideration is given for the effect of sectional size on the structure.

(b) As the unit to express carbon and silicon contents, each absolute value is used.

(c) The ranges of the structure of cast iron with various contents are easily found.

(d) The stable range of pearlitic structure is given.

(e) The effects of carbon and silicon on the structure can be compared.

From the present experiments, it is concluded that (C + Si) and Sc are undesirable as the unit to express carbon and silicon contents in the structural diagram of cast iron.

In couclusion, the writer wishes to express his sincere thanks to prof. T. Ishiwara for his encouragement and valuable advices to this work.