# Casting Science and Technology

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# Quality Control of Heavy Section Ductile Cast Iron Based on Spheroidization Theory

## Tasks

In our foundry, the graphite formation theory in cast irons has been introduced into practice. Therefore trouble was reduced and it became easier to produce the high quality product constantly than before. Heavy section ductile cast iron was produced under the Site Theory and the mechanical properties were tested to evaluate the casting.

## Procedure

The casting dimension and appearance are shown in **Fig. 1**. The chemical composition and cast designing was decided considering on the microstructure, mechanical properties and shrinkage free casting without any risers. A computer simulation was used for this purpose. To check the precision of the computer simulation, the solidification time was measured and the soundness was checked. The mechanical properties were tested at several parts in the casting, as shown in **Fig. 1**.

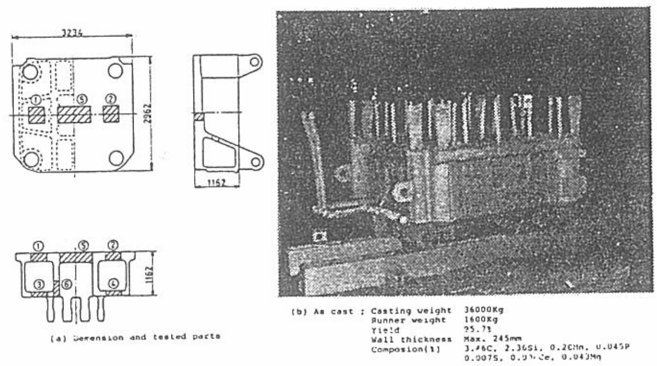
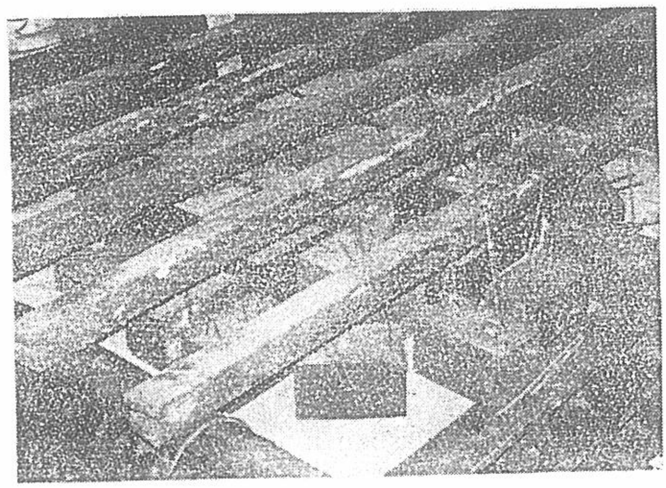



Fig. 1 Heavy section ductile cast iron studied in this work.

## Result

As the result of the simulation, a large quantity of chillers shown in **Fig. 2a** were needed to control the graphite morphology for the heaviest section and chillers were also used to succeed the riserless casting. Good matching between the simulation and practice was obtained satisfactorily.



(a) Chilling for heaviest section.

That is to say; the measured solidification time was almost same as simulated, as shown in **Fig. 2b** and also, no shrinkage was observed as simulated. The results of the mechanical tests were shown in **Table 1.** The each test value was an excellent at the each part as heavy section and the values were almost a homogeneous among the parts.

Table 1 Test results of mechanical properties in casting.

| | | PSO.2 | TS | El | RA | HB | CVN | RBS | J1c(K1c) |
|---|---|---|---|---|---|---|---|---|---|
| (2) | U | 25.6 | 38.9 | 27.3 | 23.6 | 144 | 1.5 | | |
| | | 25.3 | 38.3 | 24.6 | 21.3 | 146 | 1.6 | 18.4 | |
| | | 25.5 | 39.3 | 24.6 | 23.2 | 147 | 1.5 | | |
| | M | 25.7 | 39.5 | 20.3 | 18.1 | 143 | 1.0 | | |
| | | 25.9 | 39.6 | 21.0 | 19.1 | 140 | 0.9 | | |
| | | 25.6 | 39.5 | 21.6 | 19.4 | 140 | 0.8 | | |
| | L | 25.9 | 38.7 | 21.0 | 16.9 | 137 | 1.0 | | |
| | | 26.0 | 38.0 | 21.4 | 18.8 | 143 | 1.1 | | |
| | | 26.1 | 38.8 | 21.7 | 20.7 | 146 | 1.0 | | |
| (4) | U | 26.3 | 38.9 | 16.4 | 15.4 | 147 | 1.0 | | |
| | | 26.0 | 39.2 | 22.4 | 20.6 | 138 | 0.9 | 17.0 | |
| | | 26.2 | 38.7 | 14.8 | 17.4 | 137 | 1.0 | | |
| | M | 26.2 | 39.7 | 20.6 | 17.2 | 140 | 0.9 | | |
| | | 26.1 | 39.6 | 18.4 | 15.9 | 141 | 0.9 | | |
| | | 26.0 | 39.2 | 16.0 | 12.1 | 143 | 0.8 | | |
| | L | 26.1 | 39.9 | 25.6 | 24.1 | 147 | 1.4 | | |
| | | 26.4 | 39.9 | 21.2 | 22.3 | 146 | 1.5 | | |
| | | 26.3 | 39.9 | 24.6 | 23.2 | 143 | 1.4 | | |
| (5) | Dr | 24.7 | 32.8 | 6.0 | 8.4 | 137 | 1.5 | | |
| | | 25.3 | 33.1 | 6.0 | 11.1 | 146 | 1.4 | | |
| | | 25.3 | 33.5 | 4.2 | 9.8 | 143 | 1.5 | | |
| | U | 26.0 | 39.6 | 24.8 | 24.1 | 143 | 1.3 | | 5.9(333) |
| | | 26.3 | 40.0 | 25.0 | 24.1 | 143 | 1.3 | 18.8 | 5.8(330) |
| | | 26.3 | 39.6 | 24.0 | 22.8 | 140 | 1.3 | | 6.8(357) |
| | M | 26.3 | 39.6 | 16.0 | 13.8 | 140 | 0.9 | | 4.6(294) |
| | | 26.3 | 39.6 | 17.0 | 16.4 | 140 | 0.9 | | 6.3(344) |
| | | 26.6 | 40.0 | 19.6 | 17.7 | 143 | 1.0 | | 5.2(313) |
| | L | 26.6 | 39.3 | 21.4 | 20.3 | 140 | 1.1 | | 5.6(321) |
| | | 27.0 | 39.0 | 19.0 | 19.0 | 143 | 1.0 | | 6.7(355) |
| | | 27.0 | 38.7 | 16.6 | 16.4 | 140 | 1.0 | | 7.0(363) |
| (6) | U | 25.6 | 39.1 | 23.6 | 18.8 | 140 | 1.4 | | |
| | | 25.8 | 39.2 | 23.0 | 17.9 | 146 | 1.1 | | |
| | | 26.1 | 38.9 | 16.8 | 14.7 | 140 | 1.0 | | |
| | M | 25.9 | 39.5 | 29.2 | 25.7 | 142 | 1.1 | | |
| | | 25.2 | 39.4 | 22.8 | 19.3 | 147 | 1.3 | | |
| | | 25.3 | 39.1 | 18.0 | 16.8 | 143 | 0.9 | | |
| | L | 25.7 | 39.3 | 25.6 | 23.5 | 135 | 1.1 | | |
| | | 25.6 | 39.2 | 16.2 | 17.3 | 140 | 1.1 | | |
| | | 25.9 | 39.2 | 19.6 | 17.6 | 139 | 1.1 | | |

Nomenclature
- PSO.2 : 0.2% proof stress (kgf/mm2)
- TS : Tensile strength (kgf/mm2)
- El : Elongation (%)
- RA : Reduction in area (%)
- HB : Brinell hardness (10/3000)
- CVN : Charpy V-notch impact value (kgf-m/cm2)
- RBS : Rotating bending Stress (kgf/mm2)
- J1c : Elastic-plastic fracture toughness (Kgf/mm)
- K1c : Stress intensity factor (Kgf/mm3/2)
- U : Upper layer of wall thickness
- M : Middle layer of wall thickness
- L : Lower layer of wall thickness
- Dr : Dross layer in wall thickness

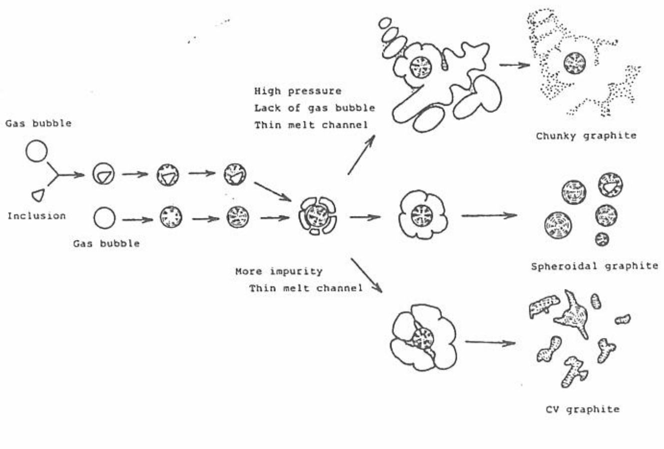
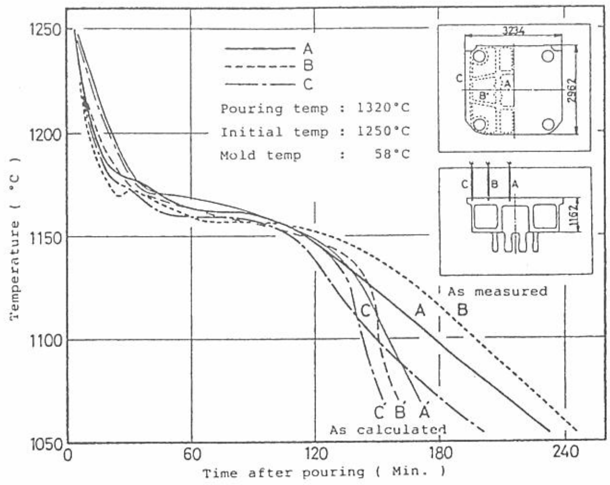



Fig. 3 Schematic illustration of graphite formation mechanism in molten iron treated with spheroidizer.




(b) Solidification cooling curve at heaviest section

Fig. 2 Result of computer simulation and practice on heavy section ductile cast iron.

## Application

The Site Theory was proposed for all graphite formation mechanism in cast irons.[1] In the case of molten iron treated with spheroidizer, the graphite formation mechanism is illustrated in **Fig. 3**, according to the Site Theory.

The idea of the Site Theory is that the graphite morphology in cast irons is just depended on the site where carbon atom is precipitated and formed as graphite and that the native growth behaviour is never changed among every types of graphite.

This theory was founded under consideration of the carbon bonding system for graphite, the state of spheroidizer element in molten iron, the solidification process, the graphite formation behaviour in solid phase, the substructure of many types of graphite, etc. The examples of the data supporting the Site Theory are shown in **Figs. 4 and 5.**

Since many factors have to be considered to produce the fine products made from ductile cast iron, it may be very advantageous for foundrymen to understand the graphite formation mechanism in cast irons like our case.

## Reference


(1) H. Itofuji, et al.; AFS Transaction, vol. 99, as published (1991).

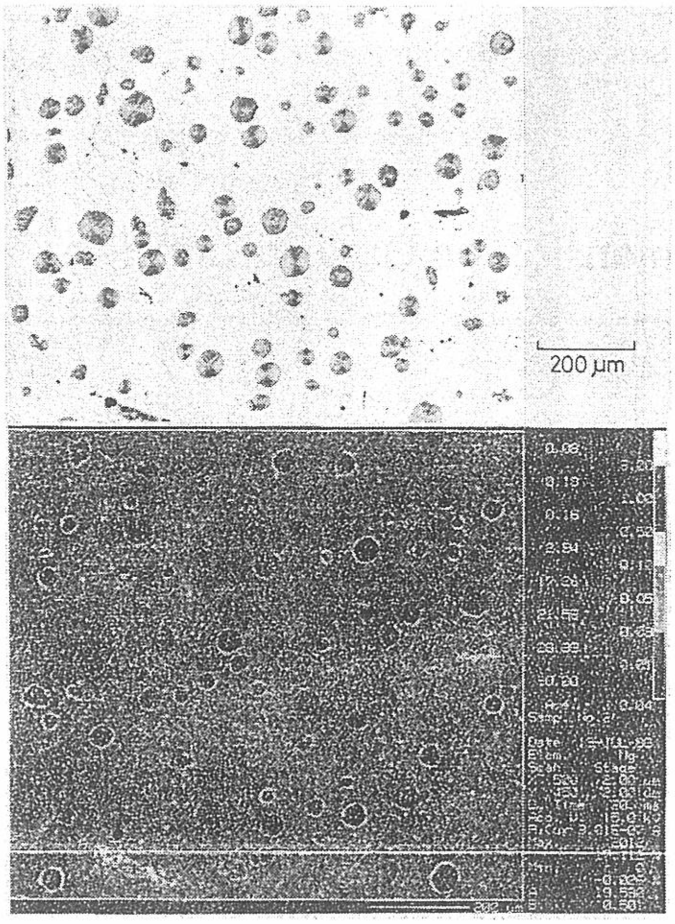



Fig. 4 Microstructure and Mg concentration in ductile cast iron.

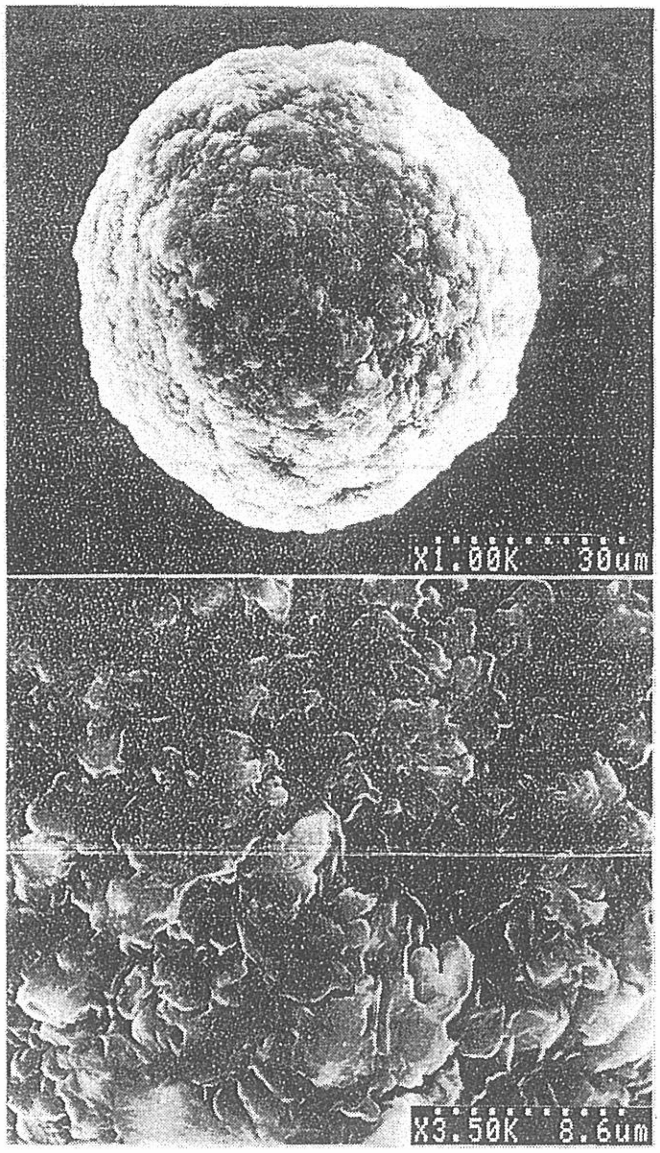



Fig. 5 SEM photographs of spheroidal graphite extracted from matrix.