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Influence of Amount of Chunky Graphite on the Mechanical Properties of Spheroidal Graphite Cast Iron

Hideaki Nakayama[1], Bai-Rong Zhao[2], Noriaki Furusato[3] , Satoru Yamada[4]
[1,2,3,4] Department of Research & Development, I Metal Technology Co.,Ltd, 4-2 Kitakandatsu-Machi, Tsuchiura-City, Ibaraki-Pref, Japan

Chunky graphite is generated in the heavy sectioned castings [1], and will be detrimental to the mechanical properties of cast irons, especially ductility and toughness [2]. However, there is little review showing change of mechanical properties by the amount of chunky graphite quantitatively.

In this study, the cylindrical casting which contained some chunky graphites was made. As base metals, highly pure pig iron and steel scrap with Fe-Si and RE-Si alloys were used. We took some specimens from the casting, and measured mechanical properties by the tensile strength test and the brinell hardness test.

Tensile strength was not affected until the chunky graphite amount of about 20%. However, when the amount exceeded this percentage, it started to get down gradually, and eventually decreased about 50MPa which is lower than the only spheroidal graphite region. Elongation was not decreased so much when the chunky graphite amount was up to about 20%, however when the amount exceeded 20%, it decreased rapidly to about 40% and remained the same. On the other hand, yield strength and hardness were not affected.

Keywords: *Cast Iron, Chunky graphite, Mechanical properties.*

1. Introduction

The cast iron parts used for construction machinery and industrial vehicles have always required reliability and durability. Consequently, they are often made of thick-walled spheroidal graphite cast iron for higher rigidity, high load, high repeated load, and resistance against shock, vibration, and heat. However, in the thick-walled spheroidal graphite castings, chunky graphite is often generated due to cooling rate and chemical composition. Chunky graphite is generally known as one of the abnormal graphite which is detrimental to mechanical properties. However, the relation between amount of chunky graphite and mechanical properties is not well known quantitatively. In this study, the influence of amount of chunky graphite on the mechanical properties of spheroidal graphite cast iron are investigated.

2. Experimental Method

As base metals, highly pure pig iron and steel scrap were melted in the 100kg high frequency induction furnace. Their fundamental chemical compositions are Fe- 3.7%C- 3.5%Si- 0.2%Mn- 0.02%P- 0.005%S. Spheroidal treatment was carried out using the sandwich method with 1.3wt% of graphite spheroidizer, 0.2wt% of Fe-Si alloy, and 0.1wt% of RE-Si alloy. Immediately after treatment, the samples were provided to chemical composition analysis, and the melt at 1603K with 0.1wt% of stream inoculant was poured into a cylindrical casting, its thickness of 70mm, its outside diameter of 200mm and its height of 100mm. To determine the mechanical properties, 20 tensile test pieces of JIS No.4 were extracted from cylindrical casting and used for the tensile test. Their brinell hardness were measured at their grip parts. The cross-sections, 5mm apart from fracture surface of a tensile test pieces, are observed for the chunky graphite. Then the chunky graphite area ratio (hereafter referred to as R_{CG}) were measured in theire microstructures by the image analysis quantitatively. The definition equation is shown in (1).

$$R_{CG} = (A_C / A_T)\times 100 \ (\%) \qquad (1)$$

where A_C is the chunky graphite area, and A_T is the all graphite area. R_{CG} was measured in five visual fields at a magnification 100. The average of these was set as the amount of chunky graphite of each test piece.

3. Results and Discussion

Figure 1 shows the typical microstructures. The matrix structures were ferrite. Chunky graphite was found to be distributed unevenly in the cylindrical casting so that R_{CG} ranged from 0 to 80%.

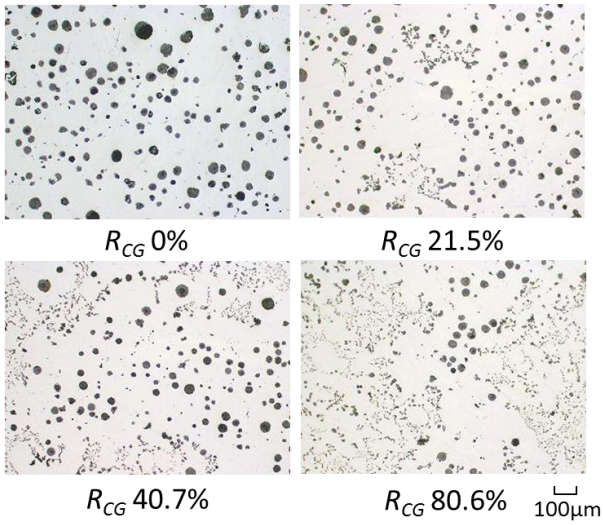

Fig.1 Typical microstructures of each chunky graphite area ratio of cylindrical casting.

Figure 2 shows the relation between R_{CG} and mechanical properties. Both yield strength and hardness remain uniform with increasing R_{CG}, and no influence of the chunky graphite were found. On the other hand, the tensile strength was found to form a moderate S-curve with increasing R_{CG}. It did not change until R_{CG} 20%, then from there to about R_{CG}40%, it started to decrease gradually and became uniform thereafter. In addition, the tensile strength of the spheroidal graphite region was 506MPa while that of the part with a large amount of chunky graphite was 457MPa, indicating a decrease of about 10%. Elongation was found to form a rapid S-curve with increasing R_{CG}. It did not decrease so much to R_{CG} of about 20%, then from there to about R_{CG}40%, it started to decrease rapidly and became uniform thereafter. The elongation of the spheroidal graphite region was 25%, while that of the part with a large amount chunky graphite was 5%, indicating about 1/5.

Tensile strength did not decrease when R_{CG} was less than 20% , when the amount of chunky graphite was very small, only the elongation was considered to be decreased due to fracture in the stage after the maximum stress of the stress-strain curve. As the amount of chunky graphite increases to a certain level, it affects before the maximum stress, resulting in the decrease of both the elongation and tensile strength.

Generally the elongation of cast iron is greatly affected by the shape of the graphite. While chunky graphite consists of refined graphites independent from each other two-dimensionally. Figure 3 shows the backscattered electron image of chunky graphite region on the fracture surface by EPMA. It can be seen that chunky graphite is three-dimensionally joined and distributed. Consequently, the fracture morphology of the chunky graphite regions is thought to resemble flake graphite and compacted vermicular graphite. We considered that when the amount of chunky graphite exceeds 20 %, break up the continuity of the matrix caused to decrease elongation suddenly.

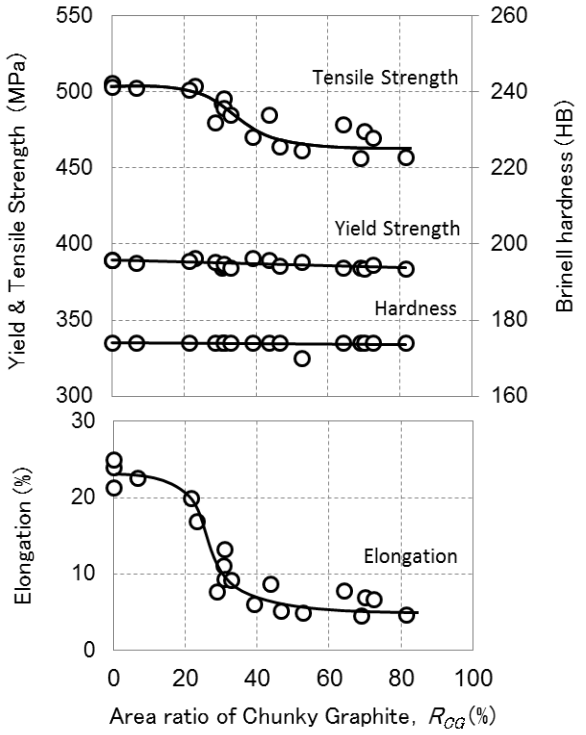

Fig.2 The relation between R_{CG} and mechanical properties.

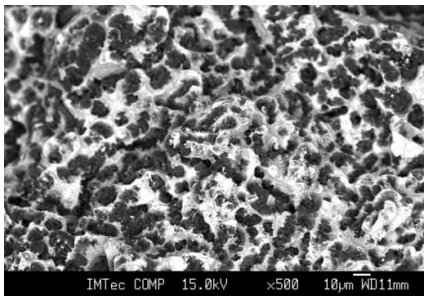

Fig.3 The backscattered electron image of chunky graphite region on the fracture surface by EPMA.

4. Conclusion

Spheroidal graphite cast iron with ferrite matrix, the amount of chunky graphite generated decreased tensile strength by about 10% most and elongation became about 1/5. Its effects on yield strength and hardness are very small. Chunky graphite had little influence of mechanical properties when the amount was less than 20%. (Omit the references.)