Bulgarian Chemical Communications, Volume 47, Number 1 (pp. 197–200) 2015

Investigation of the possibility to increase the mechanical properties of ferritic nodular cast iron

R. I. Petkov, R. Vl. Gavrilova*, L. P. Atanasov

University of Chemical Technology and Metallurgy – Sofia, Faculty of Metallurgy and Material Science, 1756 Sofia, blvd. Kl. Ohridski 8

Received December, 2014; Revised January, 2015

The aim of this study is to ensure ferrite structure of the metal base, solid-solution hardening of ferrite and hence higher mechanical performance by additional alloying. For the purpose of the experimental work brand GGG 50 is designated as the base. In its own classic form, this brand has perlite-ferrite structure. In standard cooling conditions of the cast iron its chemical composition is 3.2–3.7% C; 2.0–2.5% Si; 0.3–0.7% Mn. To study the influence of the chemical composition of the structure and mechanical properties were carried out experiments with alloys with the same carbon equivalent, but the content of Mn up to 0.15% and the silicon content varied in the range from 2.0 to 4.5%.

The analysis of results allows the conclusion, that in the presence of silicon within 3.5–3.7% and about 4.2 carbon equivalent a ferritic ductile cast iron can be obtained which satisfies the brand GGG 50.

Keywords: ductile cast iron, ferrite structure, mechanical properties.

INTRODUCTION

Good technological properties of ductile irons are that they are chemically related to the eutectic iron-carbon alloys, as are ordinary gray irons. Removing to the notch effect of graphitic inclusions as a result from transformation of shape of blade in spheroidal are reasons for higher mechanical properties (comparable and sometimes greater than those of steels) of ductile irons [1, 4]. That is achieved after adding of suitable modifiers into the melt. Specifically – requirements concerning the basic mechanical properties of ductile irons and which are set on the standards in different countries are similar. For various brands of ductile iron they provide:

- specific elongation A from 22 to 2%;
- HBS conditional yield strength $R_{0.2}$ from 220 to 850 MPa;
- Brinell hardness from 140 to 360;
- tensile strength Rm in the range from 350 to 1200 MPa;

At similar chemical composition the difference in mechanical properties of the individual brands is determined by the ratio of ferrite and pearlite in the metal base – it varies from almost 100% ferrite, wherein the relatively low strength and hardness combined with high ductility, up to 100% pearlite, wherein the high strength and stiffness combined with low ductility [5].

EXPERIMENTAL EQUIPMENT, METHODS AND MATERIALS

As is known, the pearlite is produced by diffusion of austenite decomposition. Pearlite grain structure of iron-carbon alloys are made of a soft and ductile ferrite and a hard and brittle cementite (iron carbide, Fe_3C), and depending on the shape of the cementite is constitute as lamellar pearlite or granular [4]. This heterogeneity in the structure of the pearlite is a cause of great differences in the hardness of the cast iron in the mold (170–230 HB), and as a result, because of the great heterogeneity, the workability is greatly deteriorated - it is not possible to apply high speeds of cutting, the tools take off the edge quickly and it is not possible to achieve high-end roughness on the surface [1, 5].

The aim of this study is to investigate the possibility of using additional alloying of the alloy. The idea is thus to suppress pearlite decomposition of austenite, i.e. to provide complete graphitization in the course of decomposition and obtaining a ferrite structure of the metal base just after casting, while

* To whom all correspondence should be sent:
E-mail: r.gavrilova@abv.bg

achieving the solid solutions hardenability of austenite, which would lead to the achievement of higher values of the mechanical properties of castings. In analyzing the possibilities to use alloying elements, the suggestion is that may be used only those, who meet the above requirements: first – graphitization and solid solution strength effect and second – content of elements, stabilizing pearlite - Ni, Mn, Cu, Sn and carbide-form elements – Cr, Mo, V, Mn should be restricted. Generally two elements meet the conditions – silicon and aluminum. Aluminum has a stronger effect of graphitization, but its ability of alloying is worse because of suppressed sferoidizing effect of magnesium and a marginal strength effect. For this reason, studies have been conducted with the use of silicon.

As noted, the objective of this work is to achieve a high mark ductile iron while maintaining a ferritic structure of the metal base. For this purpose, the most appropriate mark is GGG 50 (500 MPa tensile strength and 7% elongation). In the classic form, this brand has a perlite-ferrite structure (for example see Fig. 3b). For standard conditions of cooling in the casting of iron it has a chemical composition with 3.2–3.7% C; 2.0–2.5% Si; 0.3–0.7% Mn, (i.e. carbon equivalent Ce 4.125).

To study the influence of the chemical composition on the structure, the tensile strength, hardness and elongation are planned and realized experiments with alloys with the same carbon equivalent. Content of Mn up to 0.15%, silicon content was varied in the range of 2.0 to 4.5% at intervals of 0.5%; respectively the carbon content in mass percentage for each alloy is within the limits, shown in Table 1.

From the alloys cylindrical sample bodies are cast with a standard diameter (30 mm) and length of 250 mm. The proportional specimens (tubes) are made to determine the mechanical properties and standard samples are prepared for metallographic analysis of the structure [2].

The hardness is determined to Brinell method (BS 1SO 6506), [2, 3]. Measurement is made by a sphere with a diameter 2.5 mm, 187.5 kgf (1840N). The results of hardness and mechanical tests are presented in Fig. 1 and Fig. 2.

RESULTS AND DISCUSSION

The analysis of the results shows:

• Ferrite structure (100%) of the metal base in cast condition is fixed even at the third test – 3% Si and 3.25% C, but the tensile strength is 420 MPa;

Table 1. Variation of the Si content in the experimental alloys

	Content of Mn, %	Content of Si, %	Carbon equivalent
1	≤0.15%	3.5÷3.6	4.125
2	≤0.15%	3.3÷3.4	4.125
3	≤0.15%	3.2÷3.3	4.125
4	≤0.15%	3.0÷3.1	4.125
5	≤0.15%	2.9÷3.0	4.125
6	≤0.15%	2.7÷2.8	4.125

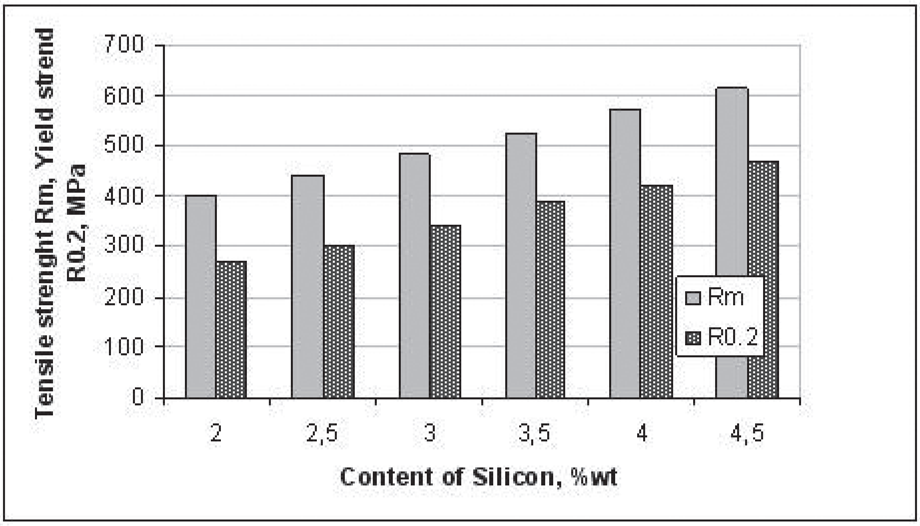

Fig. 1. Changes in tensile strength and yield strength depending on silicon

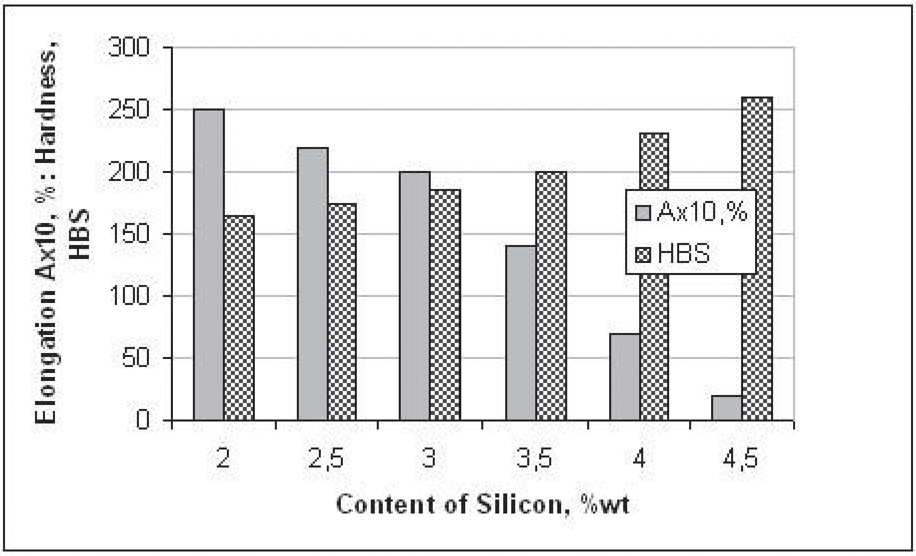

Fig. 2. Changes in elongation and HBS depending on silicon

• By increasing the silicon content, increase the tensile strength. In case of 3.5% Si the tensile strength exceeds 500 MPa in cast condition; in a 4.5% Si the tensile strength reaches 650 MPa;

• With increasing the silicon content elongation gradually decreases from 20% to 3% Si and becomes 8% to 4% Si;

• The hardness increases gradually with increasing the silicon content, as in the pure ferritic structure vary from 185HBS at 3% Si to 240HBS at 4% Si.

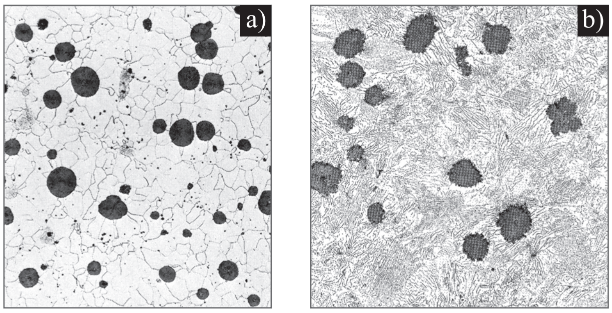

Fig. 3. a) Ferrite structure (100%) of the metal base in cast condition; b) Perlite-ferrite structure with Si content 2.0–2.5%

CONCLUSIONS

With the results of metallographic analysis and testing of mechanical properties it can be concluded that the silicon content within 3.5÷3.7% and with carbon equivalent about 4.2, ferrite ductile iron can be obtained that meets the requirements of trademark GGG 50.

REFERENCES

1. R. E. Smallman, R. J. Bishop, Modern Physical Metallurgy and Materials Engineering, Science, process, applications, Sixth Edition, Butterworth-Heinemann, Linacre House, Jordan Hill, Oxford OX2 8DP, 225 Wildwood Avenue, Woburn, MA 01801-2041, 1999.
2. H. Schumann, Metallographie, VEB DVG Leipzig 10. Auflage.
3. K. Geels, Metallographic and Materialographic Specimen Preparation, Light Microscopy, Image Analysis and Hardness Testing, Printed in U.S.A., ASTM, No. MNL46, 2007.
4. J. R Davis, ASM Specialty handbooks – Cast irons, ASM International, Materials Park, Ohio, U.S, 1996, p. 6.
5. Minkoff, The physical metallurgy of cast iron, John Wiley & Sons Ltd., Norwich, 1983, p. 102.

ИЗСЛЕДВАНЕ ВЪЗМОЖНОСТТА ЗА ПОВИШАВАНЕ НА МЕХАНИЧНИТЕ ПОКАЗАТЕЛИ НА ФЕРИТЕН СФЕРОГРАФИТЕН ЧУГУН

Р. И. Петков, Р. Вл. Гаврилова*, Л. И. Атанасов

Химикотехнологичен и металургичен университет – София, Факултет по металургия и материалознание, 1756 София, бул. „Кл. Охридски“ №8

Постъпила декември, 2014 г.; приета януари, 2015 г.

(Резюме)

Както е известно, при сферографитните чугуни високи механични показатели се постигат при перлитна структура на металната основа. Тя е хетерогенна, вследствие на което се получават големи разлики в твърдостта в рамките на отлетия обем, а това води до влошена обработваемост.

В този смисъл, целта на разработката е да се изследва възможността за допълнително легиране на сплавта, чрез което да се подтисне перлитното разпадане на аустенита, т.е. да се осигури пълна графитизация при разпадането му и получаване на феритна структура на металната основа непосредствено след леене. Цели се същевременно да се постигне уякчаване на твърдия разтвор, което би довело до постигане на по-високи стойности на механичните показатели на отлетия метал.

Анализът на възможностите за използване на легиращи елементи показва като най-подходящо добавянето на силиций. Получените резултати показват, че:

- феритна структура (100%) на металната основа в лято състояние се фиксира още при 3% Si и 3,25% C, но якостта на опън е ниска – 420 MPa;
- с повишаване съдържанието на силиций якостта на опън расте и при 3,5% Si надхвърля 500 MPa в лято състояние а при 4,5% Si достига 650 MPa;
- относителното удължение с повишаване съдържанието на силиций плавно намалява от 20% при 3% Si до 8% при 4% Si;
- твърдостта нараства плавно с повишаване съдържанието на Si, като в областта на чисто феритната структура се изменя от 185 HB при 3% Si до 240 HB при 4% Si.

От проведения металографски анализ и изпитванията на механичните показатели в настоящето изследване може да се направи заключение, че при съдържание на силиций в рамките 3,5–3,7% и въглероден еквивалент около 4,2 може да се получи феритен сферографитен чугун, който удовлетворява изискванията за марка GGG500-7.