Journal of Materials Processing Technology 214 (2014) 794–801

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

Carburiser properties transfer into the structure of melted cast iron

K. Janerka[a], M. Pawlyta[b], J. Jezierski[a,*], J. Szajnar[a], D. Bartocha[a]

[a] Department of Foundry, Silesian University of Technology, Towarowa 7, 44-100 Gliwice, Poland
[b] Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

ARTICLE INFO

Article history:
Received 3 September 2013
Received in revised form
28 November 2013
Accepted 30 November 2013
Available online 7 December 2013

Keywords:
Grey cast iron
Synthetic cast iron
Carburisers
Cast iron structure
Heredity of structure

ABSTRACT

Heredity in the microstructure of cast iron produced solely from scrap (synthetic cast iron) was considered experimentally. The carbon deficiencies were adjusted using anthracite, synthetic graphite and petroleum coke as carburisers. The small flakes of anthracite resulted in smaller graphite flakes in the final microstructure, proving that heredity is affected by the carburiser as much as by the particular "pig iron-steel scrap-cast iron" combination.

1. Introduction

The phenomenon of structural heredity in metals and alloys consists of the fact that some properties are transferred to the charge material *via* the liquid phase to the melted product. This direction, similarly to genetics in biological science, can be called genetic engineering in alloys. Trachtenberg et al. (1999) show that using the concept of 'genetic engineering' in alloys, due to its low compatibility with biogenetic engineering, is not true for physical states of 'solid–liquid–solid'. They suggest that the concept of "genetic engineering in alloys" can be used only in quotation marks and state that it would be more reasonable to use the term 'heredity'. A unit which transfers information can also be called a 'gene' by analogy; however, these are not identical. As in genetic engineering, it has been proposed that alloys be considered the "genes", the chemical-structural units (elements in structure), which move sets of hereditary information – from the charge material through the liquid phase to the melted product and further through all the processes of transformation up to product exploitation in a particular appliance and its recycling. These elements of structure can be clusters of different size, composition and morphology, activated insoluble dispersive particles (oxides, carbides, nitrides and others), and insoluble intermetallic colloidal particles.

Gagné (2006) argues that the case for the phenomenon of microheredity of structure in pig iron is very deeply rooted. He also explains that structure inheritance is not so simple and should rather be defined as the contribution of charge materials to the final characteristics of the liquid metal and its behaviour during solidification.

Bartocha et al. (2005), who studied the impact of charge materials on the structure of cast iron, which was melted on a pig iron base and without its participation in the stock, found differences in the distribution of graphite. Similarly, Janerka et al. (2013) have shown that the type of carburiser affects the structure of the melted cast iron. They also studied the influence of the type of carburiser on carburisation effectiveness (Janerka et al., 2007, 2009), and on the solidification process (Janerka et al., 2010).

2. The carburisers

As part of the study, carburisers which are the most commonly used in foundry (anthracite, synthetic graphite, natural graphite and petroleum coke) were used. For all these materials the chemical composition was checked, macro and microstructures were studied and quantitative structural studies were carried out. In the next stage, cast iron melts were made exclusively with steel scrap as the base and the carburiser added into the furnace at the same time with the rest of the solid charge. The chemical composition and carburiser description used in the studies is shown in Table 1.

* Corresponding author. Tel.: +48 32 338 55 51; fax: +48 323385518; mobile: +48 691 544 485.
E-mail addresses: krzysztof.janerka@polsl.pl (K. Janerka), miroslawa.pawlyta@polsl.pl (M. Pawlyta), jan.jezierski@polsl.pl, janjezierski@wp.pl (J. Jezierski), jan.szajnar@polsl.pl (J. Szajnar), dariusz.bartocha@polsl.pl (D. Bartocha).

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http://dx.doi.org/10.1016/j.jmatprotec.2013.11.027

Table 1
Chemical composition of carburisers used in the research (scale).

Chemical composition	C %	S %	Volatiles %	Ash %	Humidity content %	N %	H %
Natural graphite GN1	85.0	0.08	3.00	11.00	2.0	0.10	0.41
Anthracite A1	92.0	0.30	2.00	8.00	1.0	0.46	0.53
Synthetic graphite GS1	99.0	0.03	0.20	0.80	0.5	0.00	0.32
Petroleum coke KN1	98.0	0.50	0.70	0.65	0.5	1.98	0.46

The minimum carbon content is in natural graphite – around 85%. Anthracite contains 92% of carbon, synthetic graphite contains more than 99% carbon, and petroleum coke contains 98%. The microstructures of all the carburisers were analysed on a metallurgical microscope. Analyses of the microstructures of the tested carburisers showed that charcoal has a uniform structure. It contains grains of similar shape which are characterised by a compact structure and a metallic sheen. Under magnification the pores and cracks occurring within the grains are visibly arranged with some regularity. Natural graphite grains, such as anthracite, have a compact structure and a metallic lustre. Their shape is similar to the grains of anthracite. Under magnification grains can be seen, but they are much fewer in number than in the anthracite. Natural graphite contains a number of pollutants and is a very soft material. Synthetic graphite is matt in colour, the grains are of various shapes and sizes, and it has rounded edges and a porous surface. The pores are much larger than in the anthracite and synthetic graphite. It has the shape of elongated strands arranged in parallel or in the form of vortices. In synthetic graphite dense pores occur over large areas. Grain petroleum coke has a surface appearance that is similar to synthetic graphite – it has a porous surface and a matt colour. Also, microstructure pictures show similar shapes and an arrangement of pores as in the case of synthetic graphite. This similarity arises from the fact that a large proportion of synthetic graphite is produced from petroleum coke.

For the analysed materials, surface morphology of the carburisers was examined on a high-resolution scanning electron microscope ZEISS SUPRA 35 equipped with a system for analysing the chemical composition of EDAX EDS. A thin (about 20 nm) layer of gold was applied on the surface of the samples which prevented them from electrifying during observation. Figs. 1 and 2 show some of the images that were obtained at low magnification. These allow for a comparison of the shapes of whole-grain carburisers.

It can be seen that the structure of natural graphite (GN) and anthracite (A1) is compact, while synthetic graphite (GS1) and petroleum coke (KN1) are porous. Folds and strongly bent layers are visible in petroleum coke and synthetic graphite during observation of the bulk grains. Fig. 3 shows the morphology of anthracite (A1). Under magnification (10 kx) the pores can be seen as having a partially spherical shape, which was also described by Dobrzański et al. (2009); there were no flakes or sheets of graphite, whereas it was noted that the test sample was not compact, and in many areas the pores and cracks were parallel. Mineral impurities can also be seen in many areas, these comprise Mg, Ca, Fe, S, Al as well as C and O.

Sample results obtained from microanalysis on an EDS spectrometer are shown in Fig. 4.

Fig. 5 shows the morphology of natural graphite (GN). At lower magnification (1.2 kx) the surface is compact and smooth. Images obtained at higher magnification show flat graphite flakes.

Fig. 6 in the left shows the morphology of synthetic graphite (GS1). The irregular shape of the surface is visible just under magnification at 2 kx. Blank spaces (pores) of different shapes and sizes are located between the curved layers. At higher magnification the cracks and slots are seen to be arranged in parallel, while the rest of the sample consists of highly defected layers (graphite sheets) in which there are minor mineral inclusions. In contrast to the graphite flakes, which are flat, the graphite sheets are strongly bent. Their edges are jagged and irregular.

Fig. 6 in the right shows the morphology of petroleum coke (KN1). Part of the sample surface is composed of layers arranged in the form of parallel folds and sheets of graphite. In certain areas of the sample to be analysed, and in particular for observation at low magnification, the surface is smooth, though cracked. At high magnification it becomes apparent that it is made from coiled, very ragged sheets of graphite which form rolls. In their centre and between them are empty spaces – pores.

The basic structural units of carburisers are fragments of a two-dimensional hexagonal network (graphene/graphite planes) that are arranged approximately in parallel, which has been described by Oberlin (1989) and Fitzer et al. (1995). The distance between the layers of graphite is equal to or greater than 0.335 nm. In a group of well-structured materials the basic structural units are crystallites of graphite. Several graphite planes with a relatively large diameter are arranged in parallel, and the distance between them is close to the limit value of 0.335 nm. In the group of poorly ordered carbon materials the basic structural units are composed of packages consisting of several layers of graphite with a diameter of a few

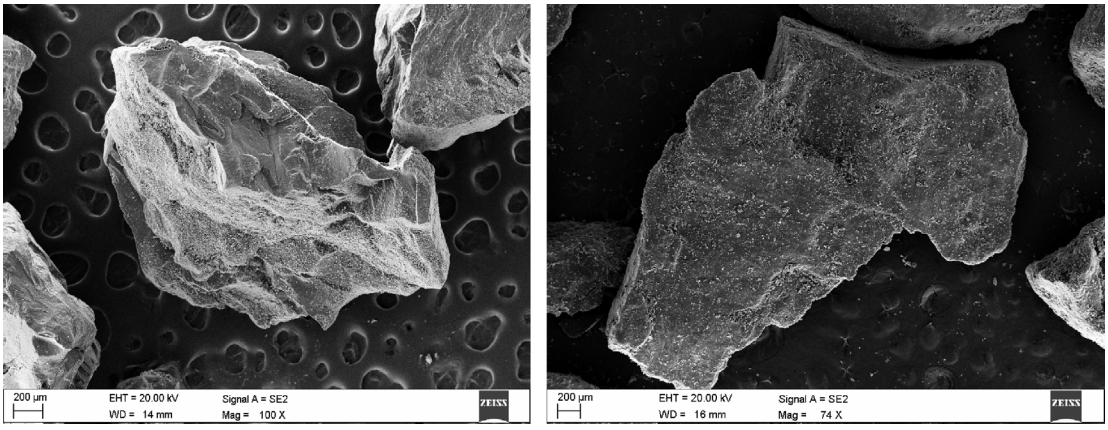

Fig. 1. Shape and morphology of anthracite grains (A1) and natural graphite (GN).