FRACTURE TOUGHNESS OF CAST IRON

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ABSTRACT

Fracture behaviour of flake graphite cast irons using micro-fractographic methods and the application of fracture toughness testing to these low strength, brittle materials.

KEYWORDS

General engineering type of Meehanite iron ; fracture behaviour ; fracture toughness testing ; fractography of fractured surfaces ; scanning electron microscopy.

INTRODUCTION

It has been accepted for many years that the fracture mechanisms of flake graphite cast irons in both the as cast and annealed condition is controlled by the brittle behaviour of graphite flakes. This phenomenon was investigated by Meyersberg (1936) Clough and Shank (1957) and finally by Gilbert (1963). The amount, size, shape and the distribution of graphite flakes in grey cast iron greatly influence its properties. The graphite flakes interrupt the continuity of the matrix and also introduce notches at their apexes, as shown by Huetter and Stadelmaier (1958). Intensive studies have been performed by Angus and Pearce (1946) on the influence of chemical composition , by Gabel (1954) on the influence of the rate of cooling of the casting in the mould and finally by Namur (1961) of the type of graphite flakes formed, all these investigations being devoted to the influence of these factors on the impact fracture characteristics of flake graphite cast irons.

Recent developments have occurred in the observation of fracture surfaces by the electron microscopy of replicas and the direct observation with a scanning electron microscope, as shown by Beacham and Pelloux (1964). At the same time the analysis and testing of grey cast irons performed by Glover and Pollard (1969, 1970, 1971) and Grüter (1975) has developed with the increased interest in fracture toughness.
In this paper results are reported of the study of the fracture behaviour of flake graphite cast iron in the as cast condition, using microfractographic methods of investigation and the application of fracture toughness testing to these low strength,britle materials.

EXPERIMENTAL PROCEDURE

General Engineering Type GD 250 Meehanite cast iron with flake graphite was investigated during this investigation. This cast iron meets the requirements of Grade 14, B.S.S. 1452 and may be used to meet Grade 17, B.S.S. 1452.

The chemical analysis of the iron is given in Table I

TABLE I Chemical Composition of Investigated Iron

C wt.%	Si wt.%	Mn wt.%	P wt.%	S wt.%
3.44	1.35	0.60	0.10	0.106

In the as cast condition the minimum tensile strength of the investigated Meehanite GD 250 iron is 250 MPa with hardness values varying from 180 to 220. The minimum impact strength is 4 Joules. The tensile strength values are valid for 30 mm diameter separately cast test bars , tested in air at 20°C. The hardness values on section thickness of casting, the testing taking place either on the test bar or at predetermined location on the casting. The impact strength is determined on unnotched standard test piece and we determined the impact values on instrumented pendulum machine.

On the investigated iron we obtained tensile strength value of 305 MPa with Brinell Hardness of 207 MPa and with impact strength values which were all below the prescribed minimum .

The metallographic structure of the investigated cast iron is shown in Fig. 1. from which it may be observed that we obtained pearlitic and pearlitic - sorbitic base matrix. In Fig. 1 b the inclusions of MnS and small quantities of free ferrite are shown.

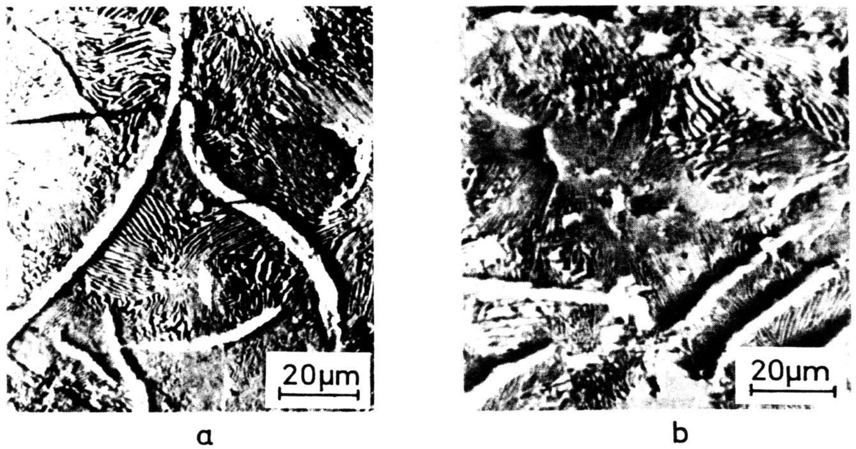


Fig. 1 Metallographic structure of cast iron
(a) pearlitic base matrix
(b) pearlitic-sorbitic base matrix

Stress - intensity factors K were determined on behalf of the Double - Cantilever - Beam Specimen which is shown in Fig. 2.

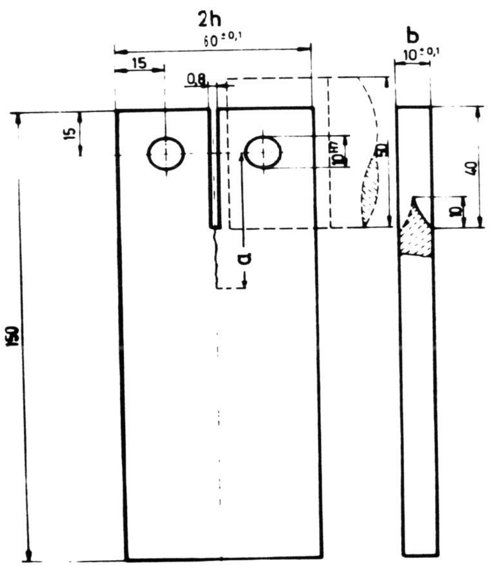


Fig. 2 Double - Cantilever - Beam Specimen

The dynamic crack was produced using an Amsler HFP - IO pulsating machine and the crack extension was followed optically , thus using a contrasting liquid. After the dynamic crack was produced, the derivation of K_Q and K_{Ic} was performed by means of the " offset procedure ". The static breaking of the sample was performed on an Amsler 600 kN tensile testing machine , using electronic registration of F and crack opening v, by simultaneous drawing of force/displacement test records. The critical stress-intensity factor was determined by the method that uses 5 % secant line and a tangential line on the force/displacement record.

After fracture toughness determinations , the fractured surfaces of the specimens were studied by direct observation on JEOL Stereoscan microscope.

EXPERIMENTAL RESULTS

The values of K_Q were determined using the following equation derived by Stellwag and Mostova (1978)

$$K_Q = \frac{3,464\ F_Q}{b\sqrt{h}} \sqrt{\left(\frac{a}{h}\right)^2 + 1,2\left(\frac{a}{h}\right) + 0,693} \sqrt{\frac{b}{b_n\,(1-\nu^2)}}$$

where b is specimen thicknes , b_n reduced specimen thickness h specimen width and ν Poisson's Ratio.

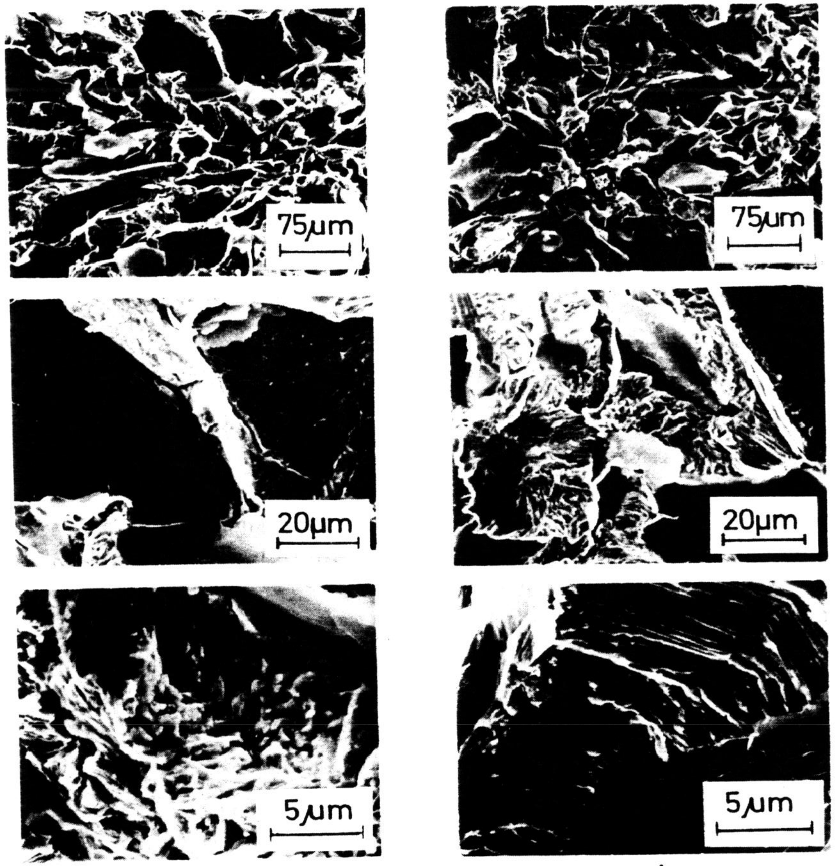
TABLE II Results of Fracture Toughness Determinations

		DCB-1	DCB-2	DCB-3	DCB-4	DCB-5
b,	mm	10	10	9,6	9,6	9,6
b_n,	mm				6,8	6,5
a,	mm	31,1	29,5	39,1	40,5	40,5
h,	mm	30	30	30	30	30
F_Q,	mm	7500	7200	6250	5400	4900
K_Q,	$MPa\cdot m^{1/2}$	26,03	24,26	25,90	28,07	26,05

Results obtained are given in Table II where the samples are designated with DCB . The evaluation of the condition of validity of the relation , that K_Q equals to K_{Ic} was not performed because the proof strength was not known. From the results in Table II it can be concluded that we obtained practically identical results of fracture toughness on all samples , and identical results we obtained also during fractographic investigations , shown in Fig. 3 .

The results of fractographic investigations of the fractured surfaces showed that there are small differences in the morphological characteristics, where at small magnifications more or less coarser grained fractures can be observed. Other results showed two other characteristic features of the fracture, fracture between graphite and metal base matrix and the fracture through the metal base matrix . The surface of graphite flakes is relatively clean and brighter lines may be seen on the surface, which are sometimes connected to irregular polygons .

For the fracture through the metal base matrix it is characteristic that the fracture surface showed channels , which followed lamellae of pearlite in the structure , und dimples on places, where the angle between fracture and lamellae of pearlite was different . This feature is characteristic for the fracture in pearlite , where microcracks proceed separately in lamellae of cementite and ferrite , and stay on the same plane if geometrical conditions allow such a position of the microcrack . On all fractured surfaces there were no signs of brittle fracture through the metal base matrix .



a b

Fig. 3 Results of fractographic surface investigations

CONCLUSIONS

The plane strain fracture toughness value of flake graphite cast iron has been determined on irons having pearlitic and pearlitic - sorbitic base matrix . The variations in K_Q values depend very much on the fracture through the matrix which showed very small variations . In all cases there was no brittle fracture character of the investigated surfaces .

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