ARCHIVES OF METALLURGY AND MATERIALS
Volume 55 2010 Issue 1

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RELATIONSHIP BETWEEN MEAN VALUES OF INTERLAMELLAR SPACINGS IN CASE OF LAMELLAR MICROSTRUCTURE LIKE PEARLITE

ZALEŻNOŚCI POMIĘDZY WARTOŚCIAMI ŚREDNIMI ODLEGŁOŚCI MIĘDZYPŁYTKOWYCH W PRZYPADKU STRUKTUR LAMELARNYCH TAKICH JAK PERLIT

This paper deals with the stereology of lamellar microstructures like pearlite in steels. Using a stereological model of this microstructure interpretation and relationship between a mean true of interlamellar spacing and a mean apparent or mean random of interlamellar spacing was presented. Theoretical considerations are compared with experimental results. As a material for experiments the pearlite – lamellar microstructure being a product of eutectoid reaction in Fe-Fe$_3$C system – has been chosen.

W pracy przedstawiono stereologiczny opis mikrostruktury płytkowej na przykładzie perlitu. Dokonano kompletnej probabilistycznej interpretacji używanych powszechnie w opisie tej mikrostruktury średnich wartości odległości międzypłytkowych oraz przedstawiono zależności pomiędzy nimi. Rozważania teoretyczne porównano z wynikami pomiarów eksperymentalnych.

1. Introduction

Pearlite is a product of eutectoid reaction in Fe-Fe$_3$C system. A growth interaction between ferrite and cementite grains forms a microstructure with lamellar morphology [1-3]. Lamellar morphology of parallel ferrite and cementite platelets in large colonies is dominating.

This kind of microstructures is quantitatively characterized by interlamellar spacings. The following denotations are usually used: l_t – true interlamellar spacing, l_r – random interlamellar spacing, l_a – apparent interlamellar spacing . All these quantities are random variables. Using the above parameters the comprehensive stereological description of lamellar microstructure consists in estimating the true interlamellar spacing distribution on the ground of the apparent interlamellar spacing or the random interlamellar spacing distribution [4-6].

The above mentioned exact, complete description of the lamellar microstructure is difficult computationally and from the practical point of view – not always needful. During examinations of the relationship between a microstructure and mechanical properties it is very often sufficient to determine a mean true interlamellar spacing on the basis of a mean random or mean apparent interlamellar spacing. Average values of apparent and random interlamellar spacing are accessible as a result of direct measurements [7-12].

2. Stereological relationships for lamellar microstructure

Stereological model of the lamellar microstructure, interesting from the view-point of interlamellar spacings can be represented by "planes batch". The planes are sets of points which correspond to the centers of thicknesses of the two nearest platelets of the same phase. These planes are parallel and the distance between both nearest planes is l_t (the distribution of the true interlamellar spacing l_t is given by density function $f(l_t)$).

On the basis of this model Czarski and Ryś [13, 14] made a full probabilistic interpretation of mean values used in the quantitative description of lamellar microstructure:

– the mean random interlamellar spacing : l_r is the estimator of the reciprocal of expected value $E(l_r^{-1})$

$$\bar{l}_r = E^{-1}(l_r^{-1}) \tag{1}$$

– the mean apparent interlamellar spacing : l_a is the estimator of the reciprocal of expected value $E(l_a^{-1})$

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$$\bar{l}_a = E^{-1}(l_a^{-1}) \tag{2}$$

- the mean true interlamellar spacing: l_t is the estimator of the reciprocal of expected value $E(l_t^{-1})$

$$\bar{l}_t = E^{-1}(l_t^{-1}) \tag{3}$$

Considering the definitions (1) , (2) , (3) Czarski and Ryś [13,14] introduced using a new manner (comparing with Saltykov [15], Underwood [4], DeHoff and Rhines [5], Vander Voort and Roosz [6]), the well known and important relation between the mean values of interlamellar spacings :

$$\bar{l}_r = 2\bar{l}_t \tag{4}$$

$$\bar{l}_a = \frac{4}{\pi}\bar{l}_t. \tag{5}$$

Making a comparison of the equations (4) and (5) it is easy to prove that:

$$\bar{l}_r = \frac{\pi}{2}\bar{l}_a. \tag{6}$$

3. Experimental procedure

A high-purity model Fe-Fe_3C alloy has been used for experiment. The chemical composition of the material is given in Table 1.

TABLE 1

Chemical composition of steel under examination

C	Mn	Si	P	S	Cr	Ni	Cu	Al	N
0,800	0,060	—	0,003	0,010	0,040	0,030	traces	0,010	0,006

In order to produce a coarse lamellar pearlite microstructure, the material was subjected to the following heat treatment: (1) austenitizing (900°C/0,5h) with subsequent transfer to lead bath at temperature 705°C, (2) isothermal annealing in the bath (705°C/3h). Microstructure has been examined using optical microscope and is shown in Fig. 1

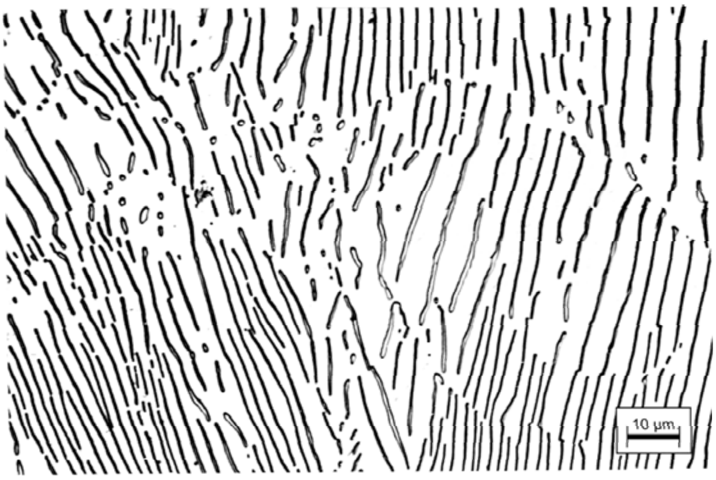

Fig. 1. Microstructure with coarse lamellar pearlite (etched in picral)

The measurements have been carried out on the image of a microstructure at total magnification x2500. The measurement of a random interlamellar spacing l_r has been performed on a random secant. The measurement of an apparent interlamellar spacing l_a has been carried out as follows: from the point of intersection of the center of a randomly selected cementite lamella with a secant a normal has being put out; the spacing of this point to the center of the next cementite lamella (on the arbitrary selected side of the secant) is an apparent interlamellar spacing l_a (Fig.2).

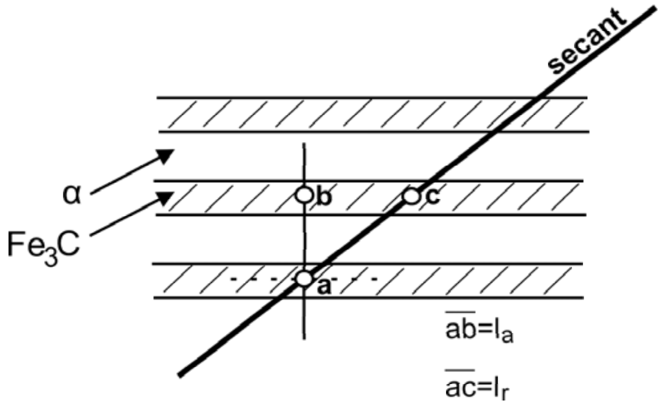

Fig. 2. Scheme of a single measurement of a random interlamellar spacing l_r and an apparent interlamellar spacing l_a

Accuracy of a single measurement was 0,2 x10^{-3} mm, that corresponds to 0,5 mm at magnification x2500. The results of measurements are presented in Figures 3-6 and in Table 2.

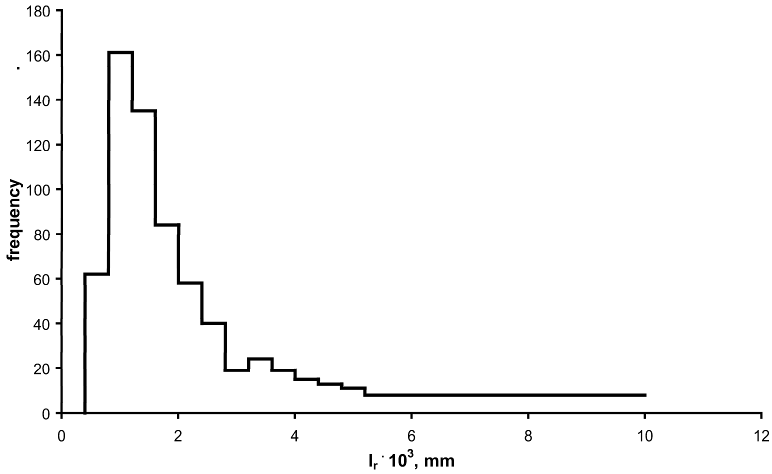

Fig. 3. Experimental distribution of random interlamellar spacing

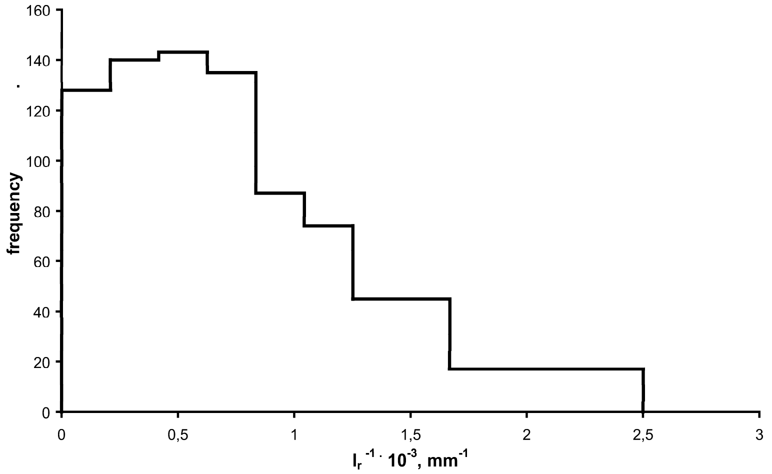

Fig. 4. Experimental distribution of random interlamellar spacing inverse

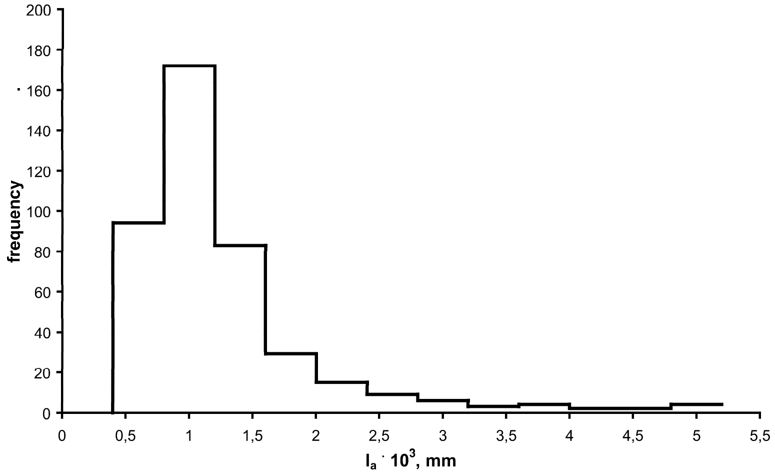

Fig. 5. Experimental distribution of apparent interlamellar spacing

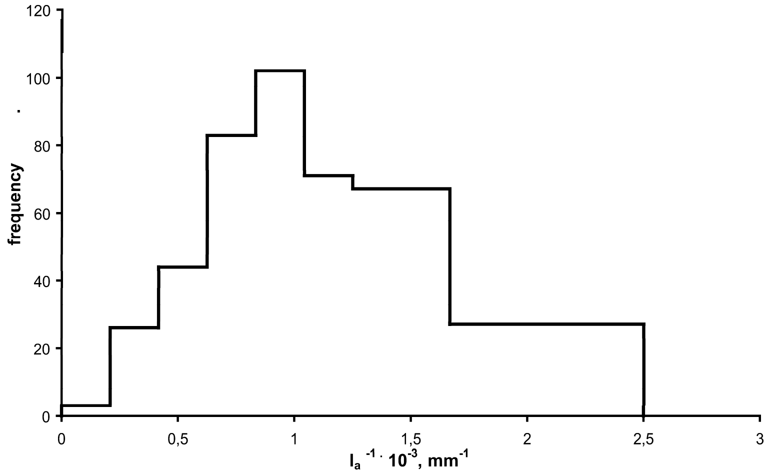

Fig. 6. Experimental distribution of random interlamellar spacing inverse

TABLE 2

Results of measurements of a pearlite microstructure (mean values have been determined on the basis of adequate empirical distributions (Fig. 3-5))

	$l_r \cdot 10^3, mm$	$l_r^{-1} \cdot 10^3, mm^{-1}$	$l_a \cdot 10^3, mm$	$l_a^{-1} \cdot 10^3, mm^{-3}$
Total number of measurements	769		423	
Mean	—*	0,6468	1,263	0,9995
Minimum	0,4	0	0,4	0
Maximum	16,1	2,5	5,2	2,5

*From theoretical point of rew not exist

Taking advantage of definitions (4), (5) the adequate mean random interlamellar spacing $\bar{l}_r$ and mean apparent interlamellar spacing mean $\bar{l}_a$ have been determined. Then, on the basis of relationships (5), (6) the true interlamellar spacing mean $\bar{l}_r$ has been defined. The results of calculations are presented in Table 3.

TABLE 3

Results of evaluation of mean values for interlamellar spacings $\bar{l}_r, \bar{l}_a, \bar{l}_t$

$\bar{l}_r \cdot 10^3, mm$	1,545	Definition (1)
$\bar{l}_a \cdot 10^3, mm$	1,002	Definition (2)
$\bar{l}_t \cdot 10^3, mm$	0,787	Equation (4)
	0,783	Equation (5)

4. Discussion

As it could be expected the minimal values of apparent and random interlamellar spacing are equal with value of 0,4x10^3 mm (Tab.2). Not making a mistake we assume that a minimal value of true interlamellar spacing is a minimal value of apparent (and random) interlamellar spacing that is 0,4x10^3 mm.

The values of true interlamellar spacing mean $\bar{l}_t$ determined on the basis of a mean random interlamellar spacing $\bar{l}_r$ and a mean apparent interlamellar spacing $\bar{l}_a$ are very close (Tab.3). Moreover the quotient of mean values $\bar{l}_r$ and $\bar{l}_a$ in case of the analysed microstructure equals 1.542, what means that the relationship (6) according to which the quotient should be $\pi/2$ is fulfilled with satisfied accuracy.

All achieved results allow to formulate a conclusion, that the considered model of the lamellar microstructure is suitable for the stereological description of a pearlite microstructure.

Acknowledgements

The financial suport from the Polish Ministry of Science and Higher Education (MNiSW) contract No. 11.11.110.405 is gratefully acknowledged.

Received: 10 September 2009.

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