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A consistent model and a new continuous reference row for the graphite structure in grey cast iron alloys

Prof. Dr.-Ing. Gotthard Wolf[1], Dr.-Ing. Claudia Dommaschk[1] Dipl.-Ing. Benjamin Aurich[1]
[1] TU Bergakademie Freiberg, Foundry Institute, Germany

Currently, we merely dispose of a visual, idealized rating standard to distinguish the single graphite structures of GJL. In a research project, we undertook to elaborate a model for a quantitative and continuous description of the graphite structure of EN-GJL. It was intended to vary the main influential factors and quantify them by measurements. The variable graphite formation was to be described by applying the definition of a structural parameter. Graphite description proceeded by determining the specific line length (LA in mm-1) between the graphite particles and their surrounding matrix. An objective determination of graphite precipitations was achieved by applying this parameter. We were also able to quantify relations with the chemical composition and the chill rate and elaborate a classification chart proposal for a continuous differentiation of graphite structures.

Keywords: *Grey Iron, Graphite structure, Cooling rate,*

1. Introduction

The development of the graphite structure in cast-iron alloys is decisive for the mechanical and physical properties. In case of GJL, the shape, dimension, quantity and arrangement of the graphite lamellae play a decisive role. The solidification mechanisms of cast iron alloys are very complex and are influenced by the chemical composition, the nucleation conditions and the cooling rate. The growth of the austenite and graphite phase of the eutectic system, in turn, depends on the undercooling, the local temperature gradient and cooling rate dT/dt [1]. The classification chart to determine the structure of graphite (DIN EN ISO 945 [2]) is currently a merely phenomenological assessment standard relating to the formation of the respective lamellar structure. It is known that a uniform formation mechanism of the graphite phase exists, however, the respective forms of graphite are not subject to a continuous transition in dependence of specific process parameters. The current classification chart according to DIN EN ISO 945 [2], used to for structural analysis, is merely a visual, idealized rating standard.

2. Graphite description

In a research project, we undertook to elaborate a model for a quantitative and continuous description of the graphite structure of EN-GJL. It was intended to vary the main influential factors in an adequate fashion and quantify them by measurements. The variable graphite formation was to be described by applying the definition of an appropriate structural parameter.

The formation of graphite structure was controlled by the chemical composition and variation of solidification conditions.

The development of various graphite morphologies was achieved by using a temperature-controlled chill. By being cast against a chill, the sample specimen was subject to a linear-directed dissipation of heat. The local solidification conditions were measured with thermocouple elements.

Graphite description proceeded by determining the specific line length (LA in mm-1) between graphite particles and their surrounding matrix. An objective determination of graphite precipitations was achieved by applying this parameter.

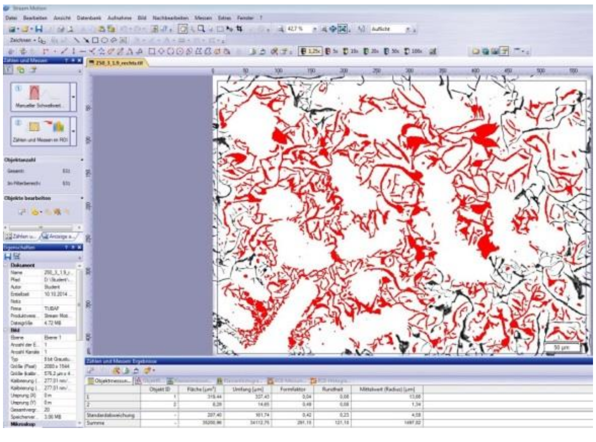

Fig.1 Example of structure analysis of grey iron

$$L_A = \frac{\sum U_G - U_R}{S_{effective}} \qquad (1)$$

3. Results

Graphite fining and an interdendritic arrangement resulted in an increase of L_A, whereas a decrease of L_A signalized graphite coarsening. A regular graphite precipitation (in accordance with DIN EN ISO 945, Graphite Structure A) results in a specific line length of $L_A < 80mm^{-1}$.

We determined that a critical cooling rate of $dT/dt_{crit} = 6$ K/min. modified the graphite structure. Depending on the chemical composition, this was found to be equivalent to a solidification time ranging between 17.5 and 23 minutes. Below dT/dt_{crit}, no substantial variation of graphite formation could be observed, a coarse A graphite developed. It followed from the experiments that the formation of microstructures strongly depended on the chemical composition once dT/dt_{crit}, had been exceeded. There was a strong dependence on the cooling rate when the carbon equivalent CE increased. Strongly under-eutectic compositions displayed a distinctly lower cooling-rate dependence. In addition, it could be demonstrated that the given C/Si ratio also exerts a strong influence on the microstructure when the CE is the same. A high C/Si ratio enhances the dependence on the cooling rate.

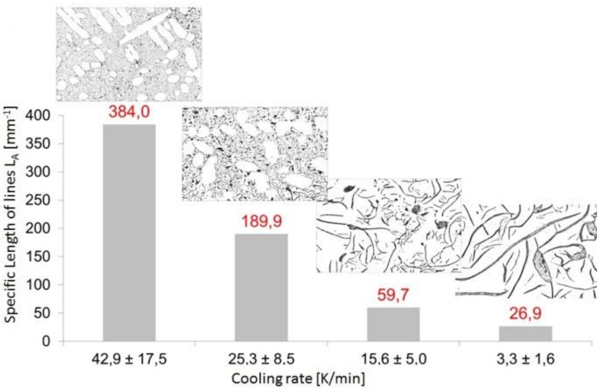

Fig.2 L_A depending on the cooling rate (nearly eutectic composition)

4. Conclusion

The results we obtained allowed for a revision of the previous, purely phenomenological classification charts that applied to GJL. Based on the data now available, we elaborated a continuous model to differentiate graphite structures. The figure 3 below shows a classification chart proposal [3].

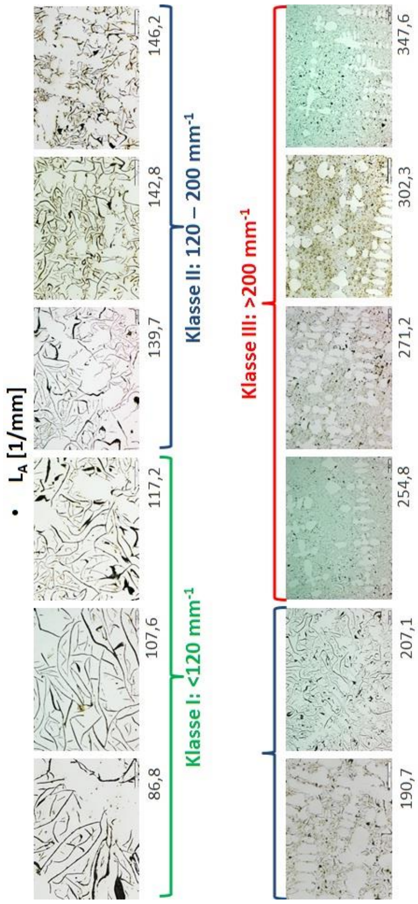

Fig.3 Classification chart proposal

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