STRUCTURE AND FATIGUE PROPERTIES OF SiMo AND SiCu TYPES OF NODULAR CAST IRON

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1. Introduction

Nodular cast irons alloyed by Si and Mo are often used for high temperature applications, for example castings of the exhaust pipes of the combustion engine or turbo charger housings. SiMo-nodular cast iron usually has a ferritic matrix, but may also contain pearlite and carbides. Increasing content of silicon increases yield strength, but lowers toughness and elongation. Therefore, the material can be very brittle at room temperature. Molybdenum partially segregates during solidification and forms a carbidic phase on grain boundaries. This carbidic network improves dimensional stability, increases tensile strength, creep resistance and corrosion resistance but reduces plastic properties [1,2].

Nodular cast irons alloyed by Si and Cu are used in various components of tribotechnical units. SiCu-nodular cast iron is characterized by a high content of pearlite in a matrix and the presence of inclusions of a structurally free copper-bearing phase. Copper is a graphitizing element and it increases the degree of pearlitization of the structure. By hardening ferrite and pearlite, copper increases strength and hardness of nodular cast iron. It also raises corrosion resistance, improves wear resistance and decreases friction coefficient of nodular cast irons [3,4].

2. Experimental methods

For experiments, two types of nodular cast irons were used:

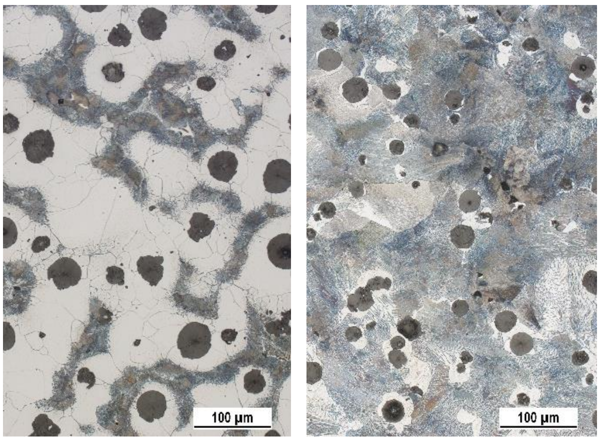
- SiMo-nodular cast iron with content of silicon 4 % and content of molybdenum 1 %, which corresponds to EN-GJS-X300SiMo4-1;
- SiCu-nodular cast iron with content of silicon 4 % and content of copper 1.5 %, which corresponds to EN-GJS-X300SiCu4-1.5.

Microstructure of the specimens was evaluated according to STN EN ISO 945 (STN 42 0461) and by automatical image analysis.

Fatigue tests were carried out according to STN 42 0362 at low frequency sinusoidal cyclic push-pull loading (stress ratio R = –1) at ambient temperature (T = 20 ± 5 °C). They were realised in the high cycle fatigue region (from 10^5 to 10^7 cycles) at frequency f ≈ 75 Hz using the fatigue experimental machine Zwick/Roell Amsler 150HFP 5100. For fatigue tests, specimens of circular cross-section with a diameter d_0 = 8 mm were used. For fatigue tests, 15 specimens from both melts were used to determine the fatigue characteristics [5,6].

3. Experimental results

From a microstructural point of view, the specimen of GJS-SiMo is ferrite-pearlitic nodular cast iron (Fig. 1a) and the specimen of GJS-SiCu is pearlite-ferritic nodular cast iron (Fig. 1b).



a) GJS-SiMo b) GJS-SiCu

Fig. 1. Microstructure of the specimens, etched by 1% Nital.

Evaluation of the microstructure of the specimens by STN EN ISO 945 (STN 42 0461) and by image analysis (shape factor, equivalent diameter of graphite, count of graphitic nodules per unit of area and content of ferrite) are presented in Tables 1 and 2.

Table 1. Microstructure according to STN EN ISO 945.

Melt	Microstructure
GJS-SiMo	90%VI6 + 10%V6 – Fe80
GJS-SiCu	90%VI6/7 + 10%V6 – Fe15

Table 2. Microstructure evaluation by image analysis.

Melt	Shape factor	Equivalent diameter of graphite [μm]	Count of graphitic nodules [mm^{-2}]	Content of ferrite [%]
GJS-SiMo	0.88	31.2	122.8	59.4
GJS-SiCu	0.84	24.3	172.4	19.7

Results of mechanical tests (tensile test, impact bending test and Brinell hardness test) are given in Table 3. The specimen of GJS-SiCu has higher yield strength $R_{p0,2}$, tensile strength R_m and Brinell hardness HBW, but lower elongation A and absorbed energy K0 than the specimen of GJS-SiMo. It has connection with the microstructure of the specimens, especially with the character of matrix (content of ferrite and pearlite) and also with size of graphite and count of graphitic nodules.

Table 3. Mechanical properties .

Melt	$R_{p0,2}$ [MPa]	R_m [MPa]	A [%]	K0 [J]	HBW 10/3000/10
GJS-SiMo	515.3	573.9	1.4	11.3	213.7
GJS-SiCu	631.1	652.7	0.7	8.0	247.3

Results of fatigue tests (relationship between stress amplitude σ_a and number of cycles to failure N_f) obtained at low frequency cyclic loading (f ≈ 75 Hz) are shown in Fig. 2.

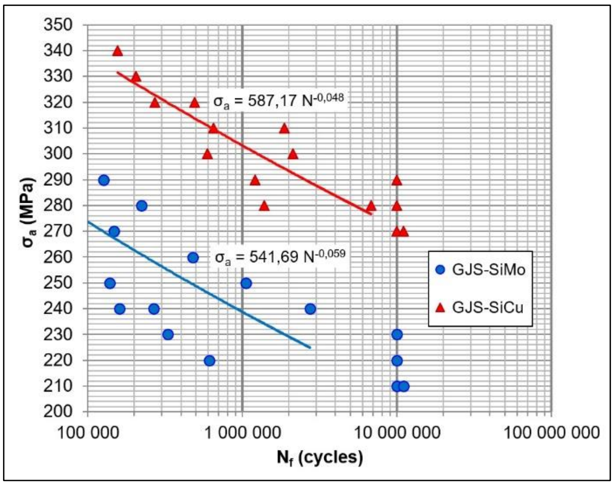


Fig. 2. Wöhler curves σ_a = f(N).

The specimen of GJS-SiCu has higher tensile strength R_m as well as fatigue strength σ_c than the specimen of GJS-SiMo.

Results of experiments have shown that the fatigue strength of nodular cast irons increases with an increasing tensile strength.

4. Conclusions

- Copper has a pearlitizing and graphitizing effect, therefore the specimen of GJS-SiCu has lower content of ferrite, smaller size of graphite and higher count of graphitic nodules per unit of area than the specimen of GJS-SiMo.
- These structural changes have brought about a change of mechanical properties, which depend especially on the character of matrix (content of ferrite) as well as on size of graphite and count of graphitic nodules. Therefore, the specimen of GJS-SiCu has higher yield strength, tensile strength and hardness, but lower elongation and absorbed energy than the specimen of GJS-SiMo.
- Fatigue strength of nodular cast irons has connection with tensile strength. The specimen of GJS-SiCu has higher tensile strength, therefore it also has higher fatigue strength than the specimen of GJS-SiMo.

Acknowledgements

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