Journal of POLISH CIMAC
Faculty of Ocean Engineering & Ship Technology
GDAŃSK UNIVERSITY OF TECHNOLOGY

EMPIRICAL EXAMINATION OF THE IMPACT OF THE CYCLE ASYMMETRY COEFFICIENT OF THE LOAD ON THE FATIGUE LIFE OF S355J0 STEEL

Grzegorz Szala

University of Technology and Life Sciences in Bydgoszcz
ul. Prof. Kaliskiego 7 85-789 Bydgoszcz, Poland
tel.: +48 52 340 82 95, fax: +48 52 340 82 71
e-mail: gszala@utp.edu.pl

Abstract

In the calculations of the fatigue life of structural components subjected in service load conditions to stochastic loads the load spectra being a set of sinusoidal cycles of different asymmetry occur. The cycle asymmetry is characterized by the asymmetry coefficient $R=S_{min}/S_{max}$ In the case of load mentioned above, R coefficient changes in wide limits from $-\infty$ to $+\infty$. In the work the empirical examinations of the impact of the cycle asymmetry coefficient of the load on the fatigue limit of S355J0 steel are presented.

Keywords: *fatigue life, two-parametric characteristics, S355J0 steel*

1. Introduction

The elaboration on the random service load of the structural components in form of spectra and programms of load applied in calculations and programmed examinations of fatigue life leads to determination by methods of counting the cycles, sets of cycles of various values of the cycle asymmetry coefficient $R = S_{min}/S_{max}$.

Spectra of variable cycle parameters (S_a, S_m) or (S_{min}, S_{max}) are depicted in form of so called correlation tables [1].

Experimental data concerning the cyclic values of materials in range of the high-cycle fatigue known in the literature concern in most cases the determination of the S-N curves in conditions of fatigue limit under oscillating load (R = -1), more seldom pulsating load (R = 0). In the work the examination with the variable value of the R coefficient are described, as well as two-parametric fatigue characteristics elaborated on their basis. The problem has been illustrated with results received for S355J0 steel (former 18G2A).

The basis of the determination of the fatigue diagrams in system amplitude S_a – mean value S_m of stresses are, S-N curves described also in the literature as Wöhler curves. These diagrams are presented in various forms, e.g.: $S_a(N)$, $S_{max}(N)$, and so on. In the figure 1 the set of diagrams $S_a(N)$, drawn with assumption of the constant value of the cycle asymmetry coefficient R = const, has been depicted. The privileged diagrams from the given set are the S-N curves for R = -1 (oscillating load of $S_m = 0$) and for R = 0 (pulsating load $S_{min} = 0$). For the durability $N>N_0$, the fatigue limits have been marked on the diagram with points: 1- R_{-1}; 2- $0{,}75 \cdot R_{-0,5}$; 3- $0{,}5 \cdot R_0$ and 4- $0{,}25 \cdot R_{0,5}$ respectively.

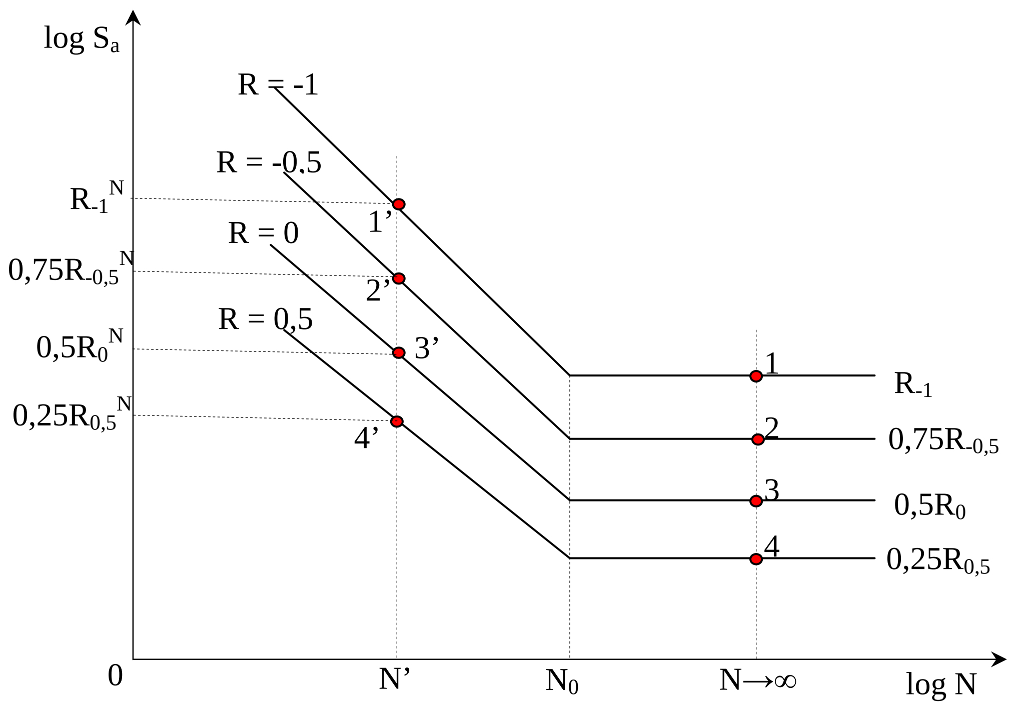


Fig. 1. Set of diagrams S_a drawn by assumption of the stable value of the cycle asymmetry coefficient R = const.

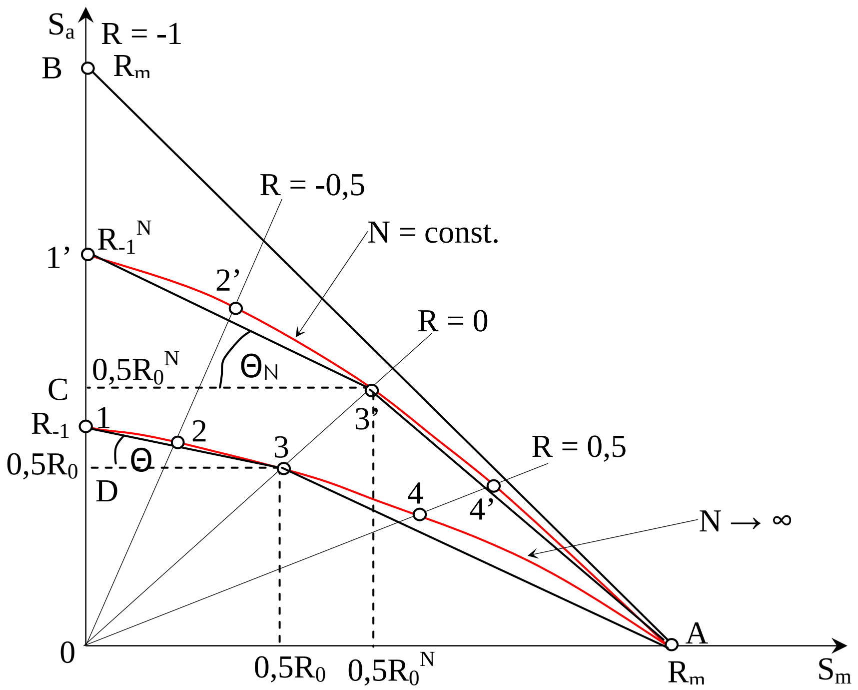


Fig. 2. Diagrammatic depiction of the diagram of two-parametric fatigue characteristics $N(S_a, S_m)$.

On the base of these points a diagram of fatigue limit 1-2-3-4 shown in the figure 2 has been drawn. Similarly, any line of constant value N=const. can be drawn. For N´ from the diagrams in the fig. 1 one receives respectively points 1´, 2´, 3´, 4´, transferred to the fig. 2 they give a line 1´-2´- 3´- 4´.

2. Fatigue examination of the samples of S355J0 steel

Fatigue examination of the samples of S355J0 steel have been conducted for the following values of the cycle asymmetry coefficient R: 0; -0,5; -1,0; -1,25; -2,0. In the literature the research results for R < -1do not occur, which corresponds to the negative average values of the cycle. Data concerning the fatigue properties, static and cyclic, have been shown in table 1.

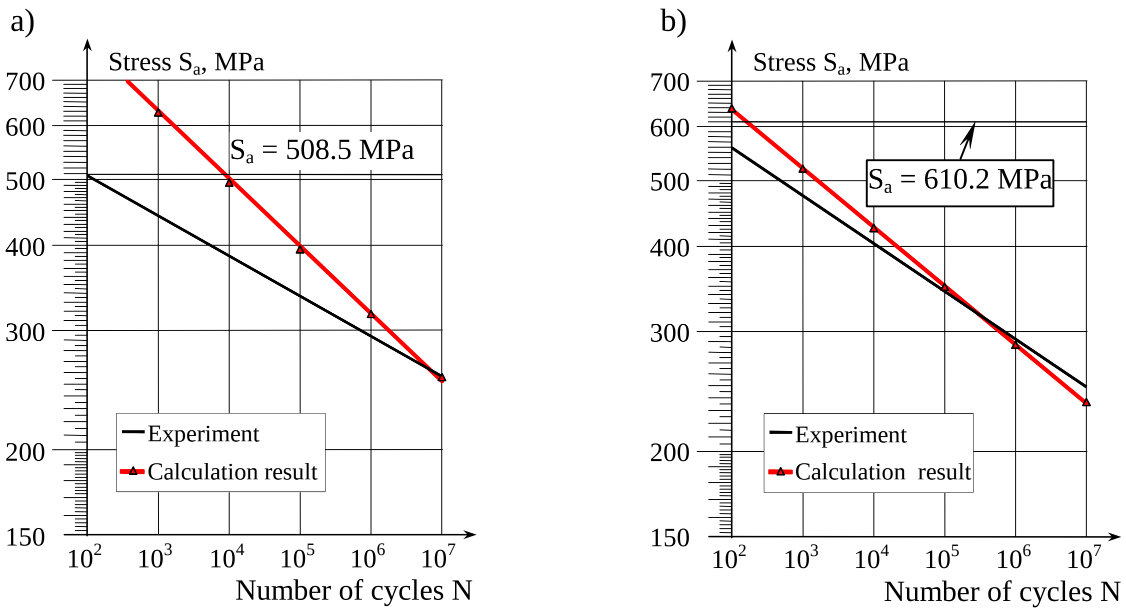
Table 1. Properties of S355J0 steel

R_m	R_m	E	A_5	Z	R_{-1}	N_o	m_o	C_o
MPa	MPa	MPa	%	%	MPa			
678	500	$2{,}08 \cdot 10^5$	17,2	59,8	274	10^6	12,33	$1{,}156 \cdot 10^{36}$
commentary: R_m – material tensile strength, R_e – material yield point, E – Young's modulus, A_5 – elongation, Z – contraction, R_{-1} – fatigue limit for R = -1, N_o; m_o; C_o – constants from the S-N curve								

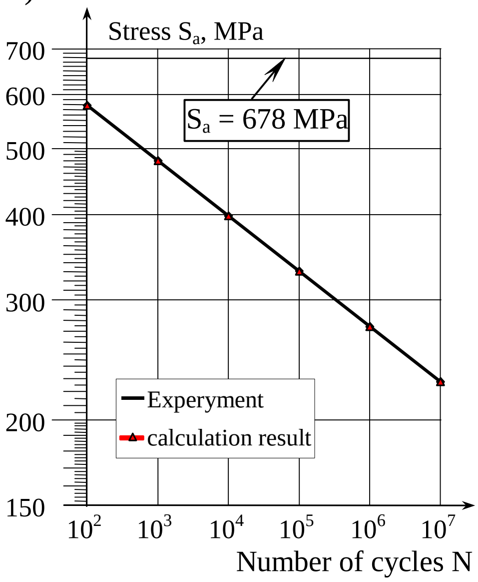
On the base of the research results the S-N curves for specified values of the coefficient R have been determined, as well as a diagram of two-parametric fatigue characteristics $N(S_a, S_m)$ has been elaborated on theirs basis. In the fig.3 fatigue diagrams for S355J0 steel for the cycle asymmetry coefficient R have been depicted: a) R = -2, b) R = -1.25, c) R = -1.0, d) R = -0.5, e) R = 0.
General description of the fatigue diagrams has been described by formula (1):

$$\log S_a = -a \log N + b \tag{1}$$

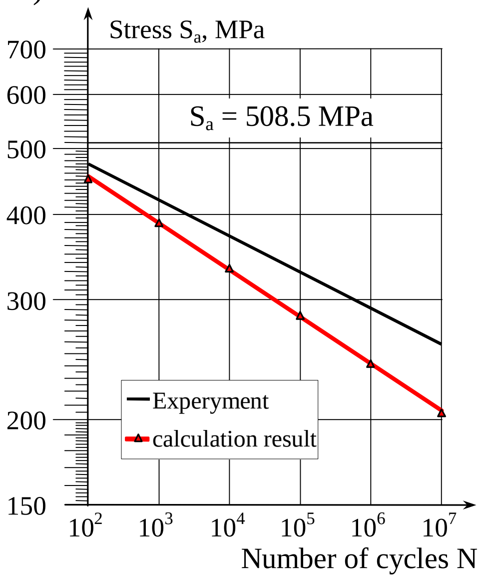
where constants a and b for the cycle asymmetry coefficients of the cycle R, assumed above, have been compiled in table 2



c)



d)



e)

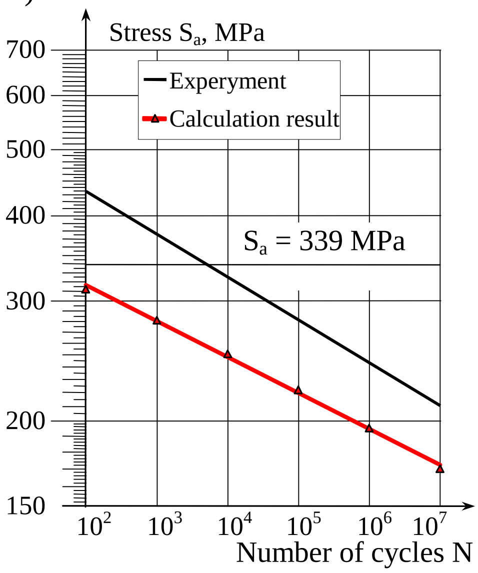


Fig.3. Fatigue diagrams for S355J0 steel for the cycle asymmetry coefficient R have been depicted: a) R = -2 b) R = -1.25, c) R = -1.0, d) R = -0.5, e) R = 0.

Table 2.: Constant values a and b

	Cycle asymmetry coefficient R				
	0	-0,5	-1,0	-1,25	-2,0
a	-0.0628	-0.0528	-0.0811	-0.0703	-0.0592
b	2.7630	2.7810	2.9247	2.8873	2.8233

3. The analysis of the research results and conclusions

S-N curves for the mentioned values of the coefficient R and the diagram of two-parametric fatigue characteristics $N(S_a, S_m)$, elaborated on their basis, have been shown in the figures 4 and 5. The data included there can be a basis for calculation of structural components, especially subjected to the impact of random load of wide spectrum.

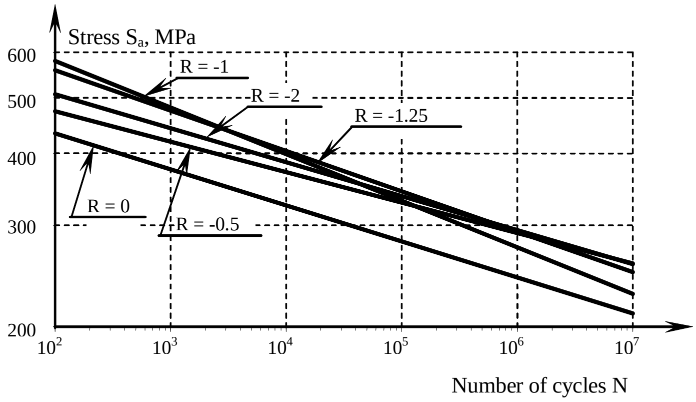


Fig. 4. Fatigue diagrams for S355J0 steel for the cycle asymmetry coefficient R: 0; -0,5; -1,0; -1,25; -2,0.

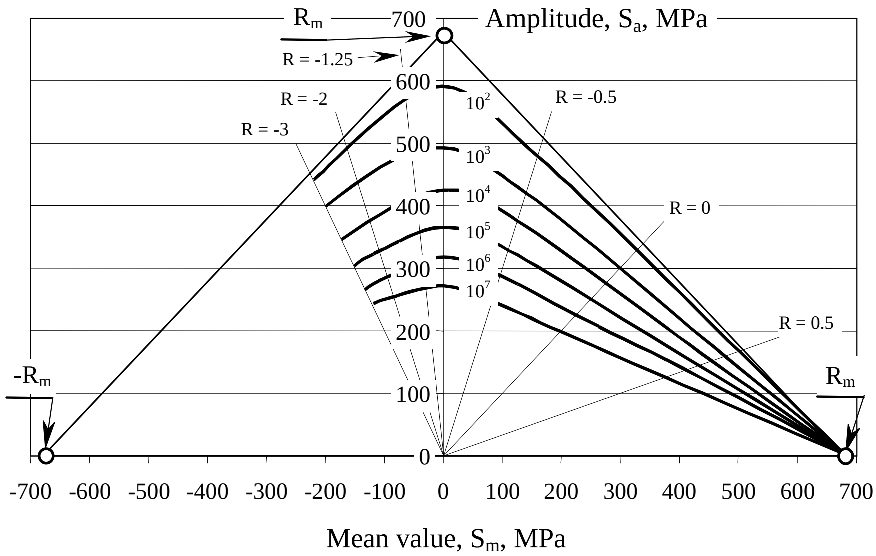


Fig. 5. Experimental two-parametric fatigue diagram for S355J0 steel.

On the base of these results also the verification of the two-parametric models of fatigue characteristics can be done.

Reference

[1] Ligaj, B., *Wpływ wybranych programów obciążeń wygenerowanych na podstawie tablicy korelacyjnej na trwałość zmęczeniową stali 18G2A,* Problemy Eksploatacji – Zeszyty Naukowe 3/2007 (66), ss. 129-146.

[2] Ligaj, B., Szala, G., *Uogólnienie wykresu zmęczeniowego Goodmana na zakres wysokocyklowego zmęczenia*, Materiały XXIII Sympozjum Zmęczenia i Mechaniki Pękania, Bydgoszcz – Pieczyska, 2010.

Note : This work has been elaborated in the frame of the project No. 0715/B/T02/2008/35 financed by Polish Ministry of Sciences and Higher Education