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VERIFICATION OF SELECTED METHODS FOR RAPID DETERMINATION OF WöHLER CURVE CONSIDERING HIGH-CYCLE FATIGUE

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Abstract

The researches considered the problem for analytic determination of fatigue characteristic, treating the methods as rapid and approximate estimation of true curves. Selected two methods are presented. The selection was made on the grounds of popularity of the proposal. True characteristics were juxtapositioned with estimated ones, taken from reaches published in the references. A critical comparison of characteristics of both methods was made. Analyses for correct functioning of both methods were made on the grounds of researches on steel test samples. The result of the researches is presented in quantitative as well as qualitative form.

Keywords: *fatigue strength, fatigue curves, analytic methods for Wőhler characteristics estimation.*

1. Problem formulation

Determination of Wöhler curve for construction elements or materials according to recomendations of relevant standards e.g. [7] provides very precise result (which is an advantage of the approach), but unfortunately, due to time of realization for the resarches, it generates considerable costs (which is a disadvantage of the method) . The standard [7] recomends resarches on at least 5 levels of load, minimum 3 test samples each with frequency of load change 5 ÷ 100 Hz. It is also worth mentioning, that the result is very conservative as far as its connection with conditions of reserches are concerned.

Such situation has lead in references to numerous propposals of analytic methods as well as analytic methods supported with simple experiment, aiming to estimated (rapid too) determination of Wöhler characteristics. The methods are mainly designed for enginerring use.

2. Presentation of selected methods

The following methods were selected for the range of high-cycle strength. They enable to determine estimated fatigue curve after performing a simple experiment (tensile strength test). Another factor which influenced the selection of the methods was the ease of use for an engineer.

Recomended approach described in procedures of FITNET ([5]) assumes the use of general knowledge on fatigue reaction of some groups of materials in specified load conditions. Values on - fig. 1 – depend on the type of stress dominating during the fatigue process of destruction (m = 5 for normal stress and m = 8 for tangential stress). The value of fatigue limit is determined for point 10^6 of cycles. The above mentioned regards steel (excluding austenic steel) and cast steel. For other construction materials and already mentioned austenic steel, for the range of number of cycles from10^6 to 10^8 cycles, it is estimated to use m_D, respectively 15 and 25.

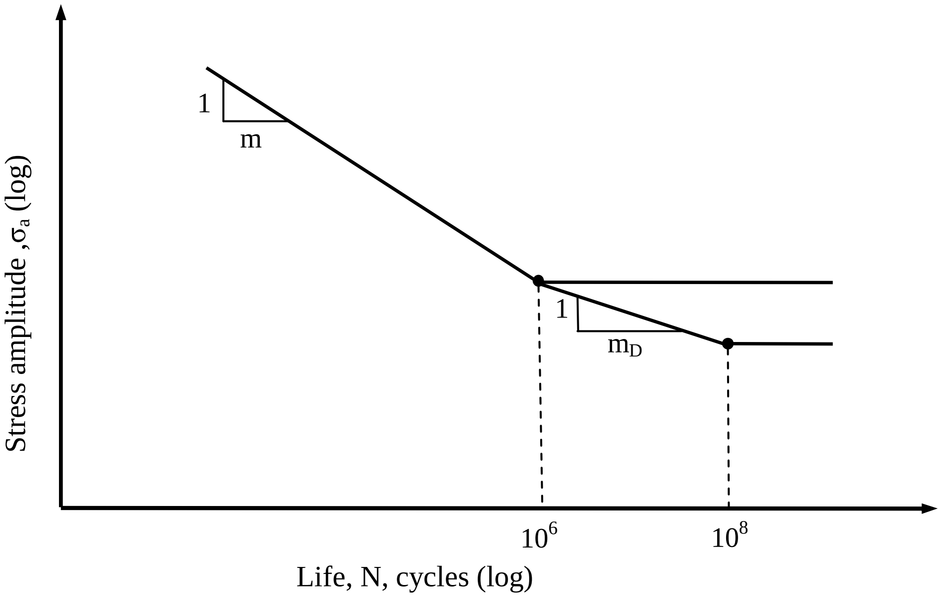

Fig. 1. Fatigue curve - estimated Wöhler curve according to [5] (designations as of the source work)

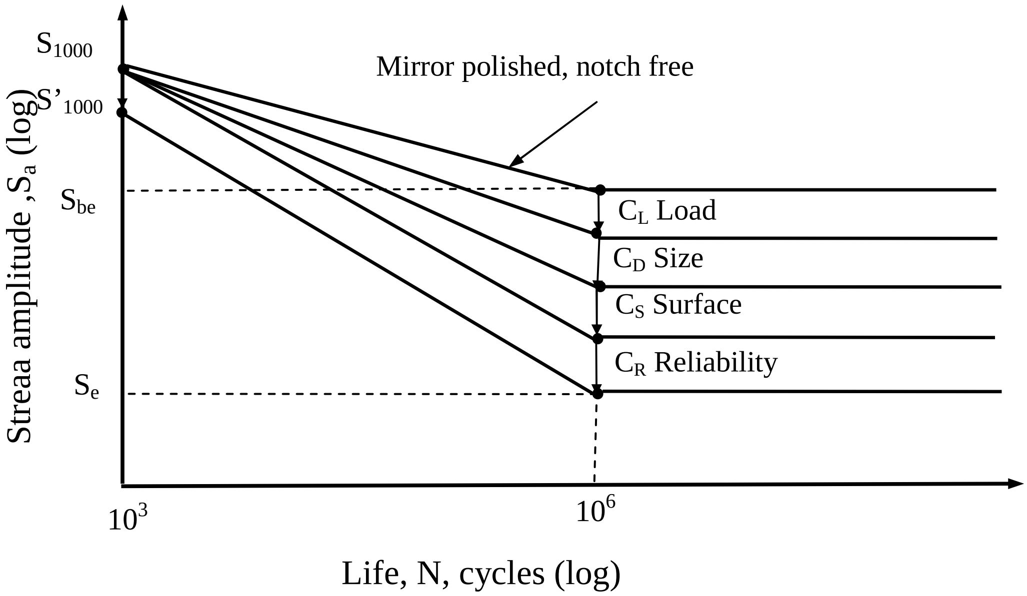

Fig. 2. Fatigue curve – modified curve S-N according to [3] (designations as of the source work)

The work [3] presents the method where determination of the line corresponding to limited fatigue strength is based on the knowledge of temporal tensile strength R_m. The value is easy to obtain via experimental methods, the data identifying the precise construction material (batch, delivery etc.). According to the data, one determines points: S_{1000} – on tensile axis and S_{be} (fatigue limit) connected with fatigue life expressed via base number of cycles.

$$S_{1000} = R_m \cdot w_1, \tag{1}$$

where:

w_1 – depends on the type of material ans type of load [3],

$$S_{be} = R_m \cdot w_2, \tag{2}$$

where:

w_2 – depends on the type of material and is connected with indication on recomended base number of cycles (on fig. 2 for example 10^6) [3].

Both presented methods take calculations for smooth test samples (basic curves) into account and for test samples (quasi-construction elements) with defined state of the surface, with respect to the scale effect and the type of employed loads. It is briefly showed on figure 2.

3. The scope and verification method for analysed approaches

In order to perform verification of the above mentioned methods, required data were defined to enable determination of fatigue life according to the procedures. After required information had been obtained, determination of fatigue curves for individual materials was performed and presented on one figure. The results were used to perform quantitative analysis for methods of determination of characteristics according to the methodology from procedures of FITNET and publications [3]. The quantitative analyses employed values of unlimited fatigue life. Preliminary verification employed data of the following materials:

- S235JR to raw state [6],
- S355J0 in raw state [4],
- 15Cr2 quenched and tempered [6],
- 34CrMo4 normalised [1],
- 42CrMo4 after plastic forming [1],
- C40 normalised [1],
- C45 normalised [2],
- SAE 8630 quenched and tempered [1].

4. Verification results

Verification results presented as follows. Figures 3 to 8 illustrate lines corresponding to high-cycle fatigue characteristics for experimental data and estimated characteristics according both analysed methods.

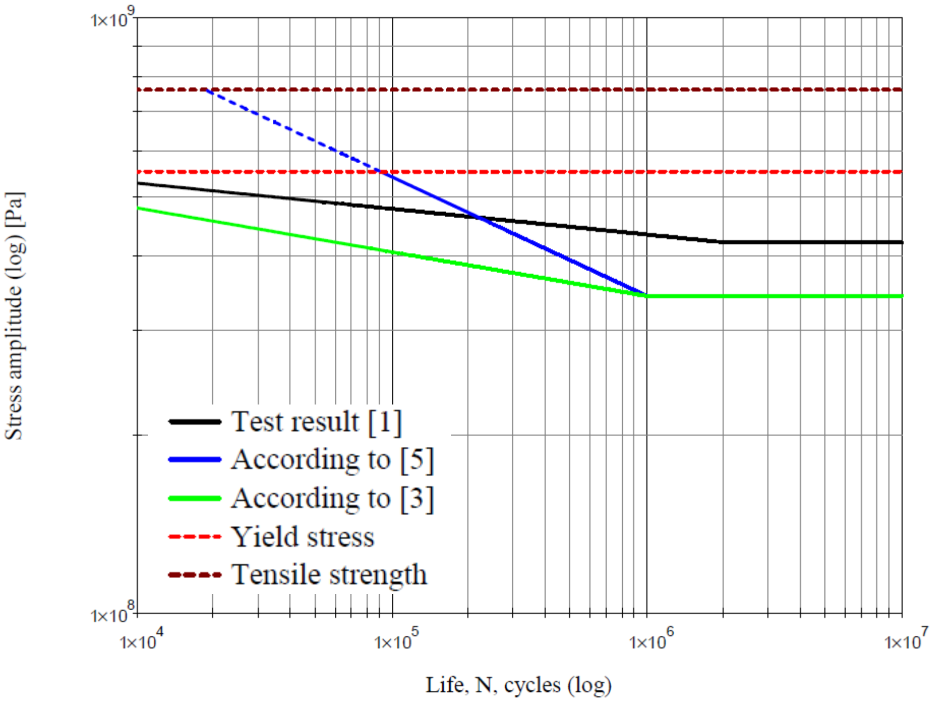

Fig. 3. Diagram presents comparison of estimation methods for high-cycle fatigue strength for 42CrMo4 steel after plastic forming

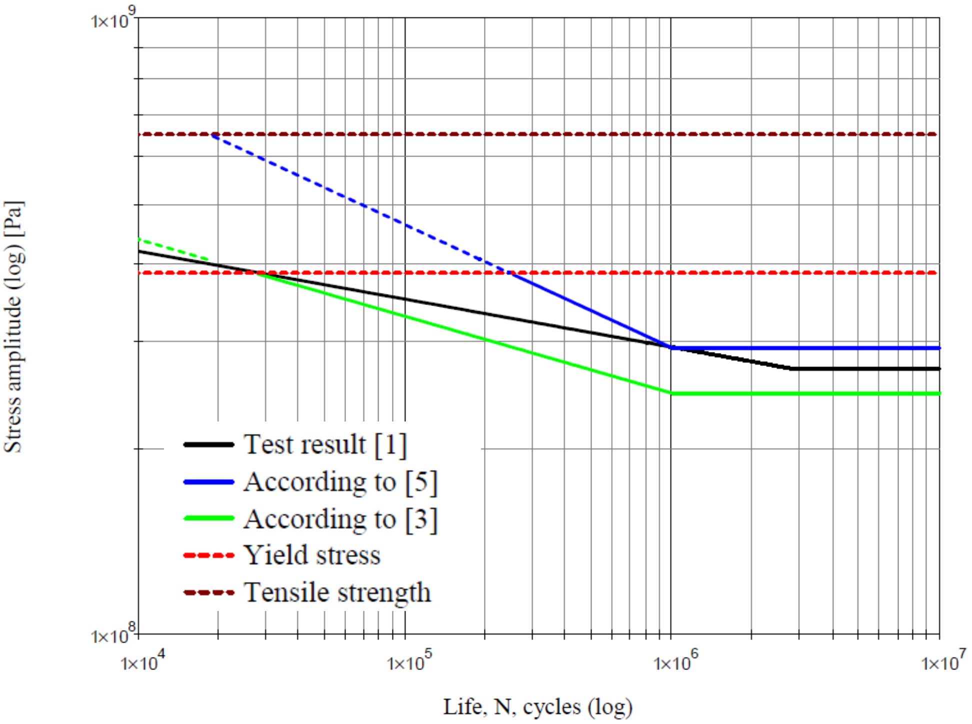

Fig. 4 Diagram presents comparison of estimation methods for high-cycle fatigue strength for C40 normalised steel

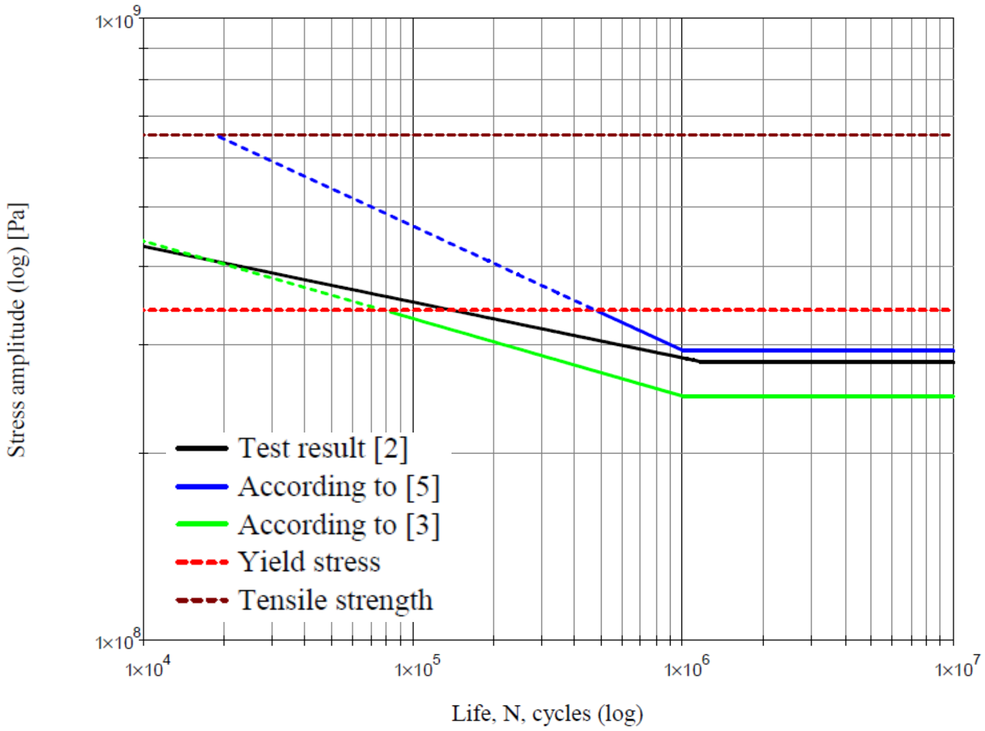

Fig. 5 Diagram presents comparison of estimation methods for high-cycle fatigue strength for C45 normalised steel

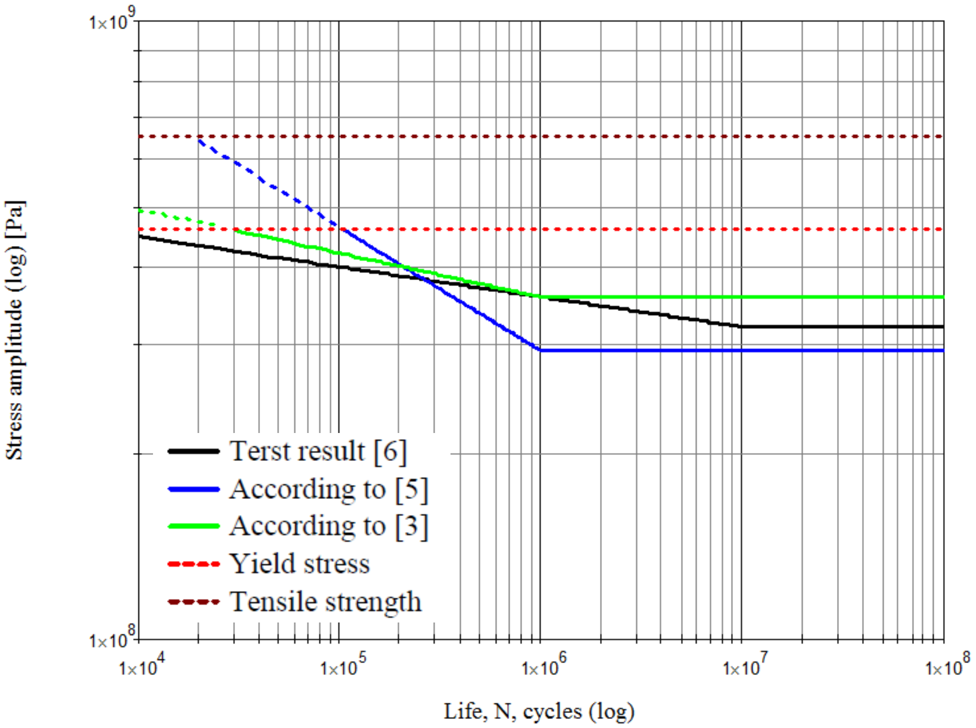

Fig. 6 Diagram presents comparison of estimation methods for high-cycle fatigue strength for 15Cr2 quenched and tempered steel

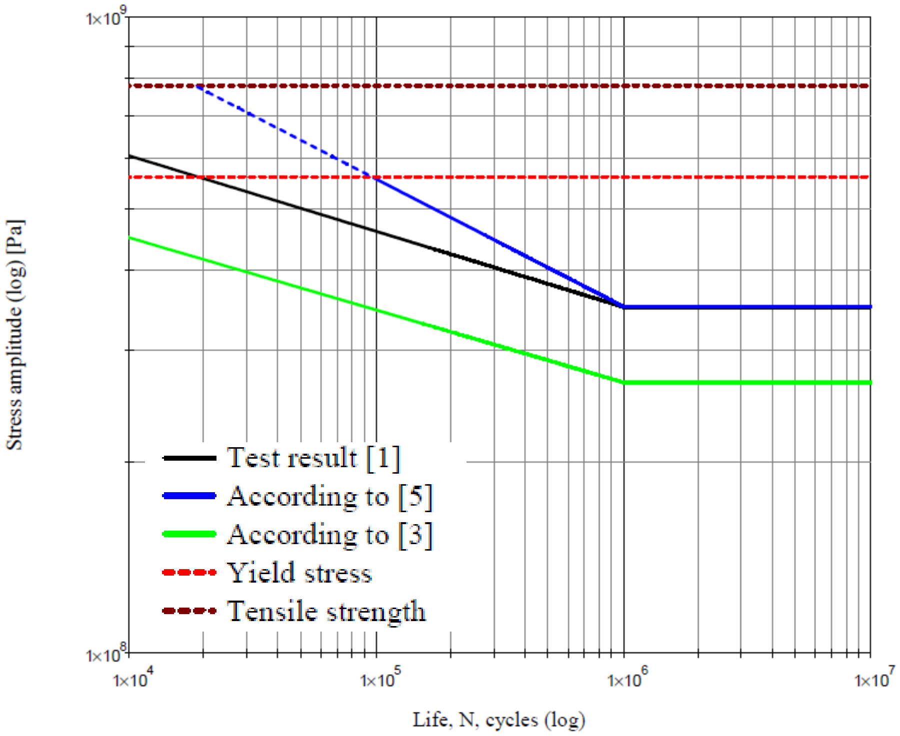

Fig. 7 Diagram presents comparison of estimation methods for high-cycle fatigue strength for 34CrMo4 normalised steel

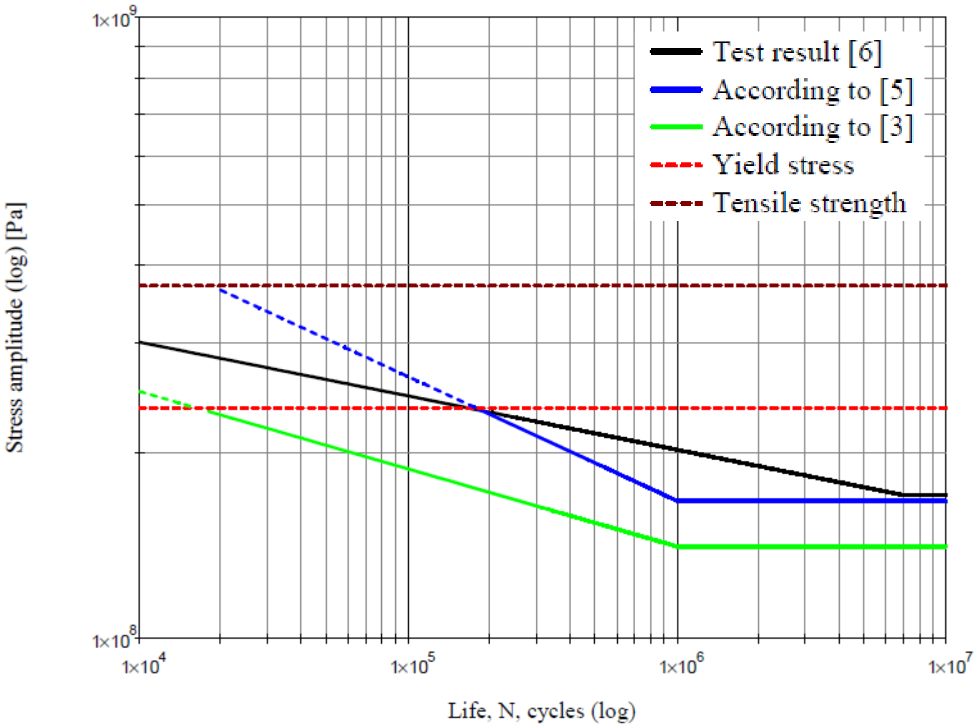

Fig. 8 Diagram presents comparison of estimation methods for high-cycle fatigue strength S235JR raw state steel

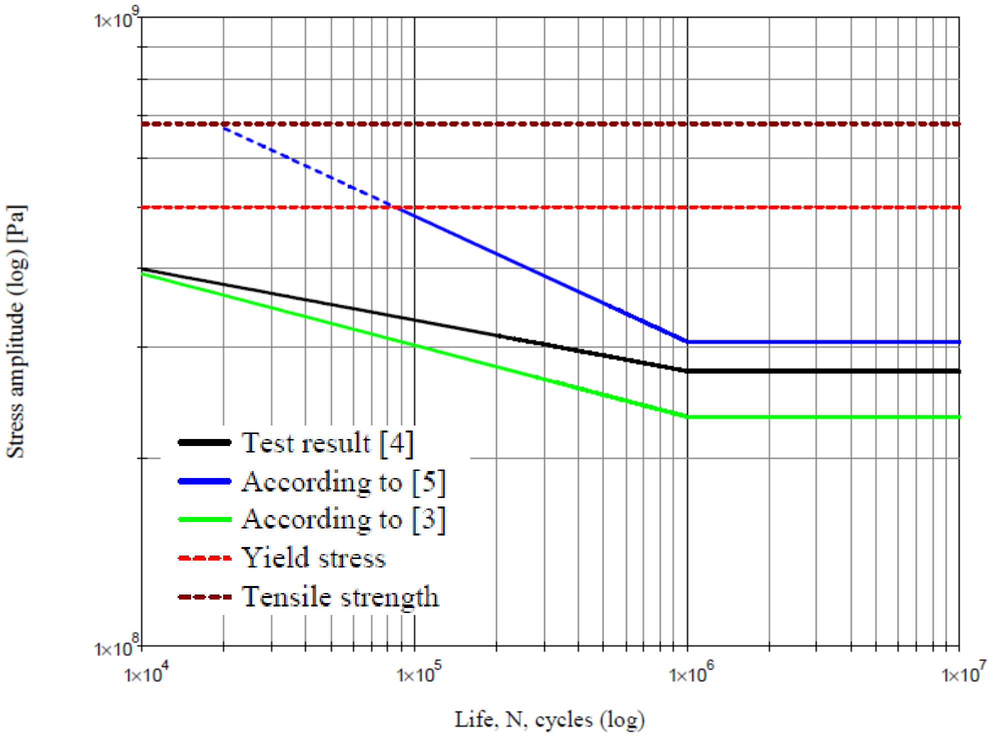

Fig. 9 Diagram presents comparison of estimation methods for high-cycle fatigue strength for S355J0 raw state steel

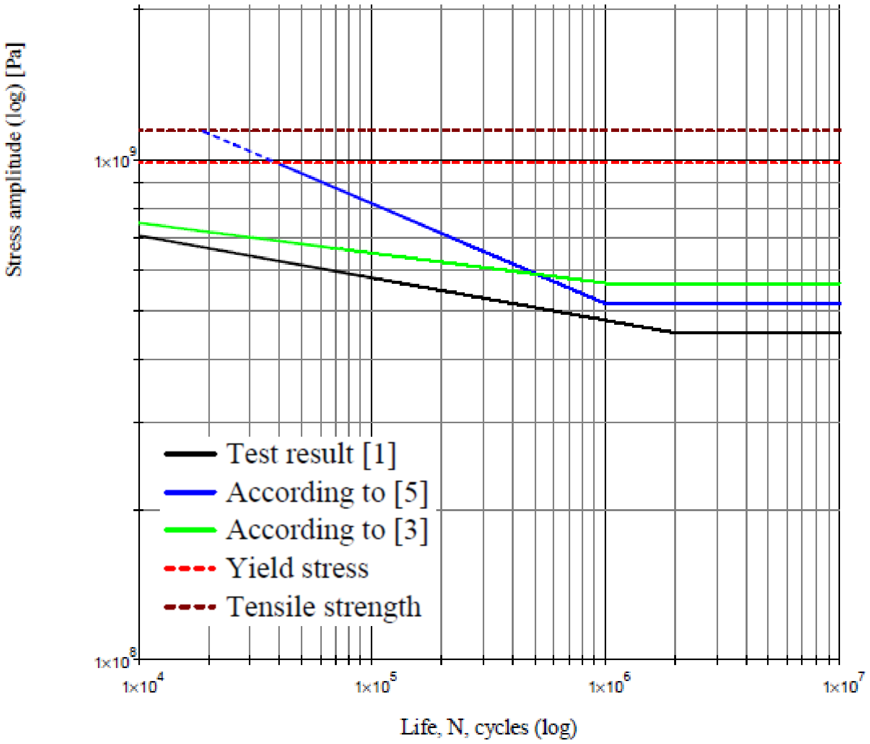

Fig. 10 Diagram presents comparison of estimation methods for high-cycle fatigue strength for SAE 8630 quenched and tempered steel

5. Quantitative and qualitative analyses

Diagram line presented on figures 3- 8 enable to perform qualitative analysis in the scope of their interlocation (on the safe side +, on the danger side -, crossing curves +/-). It is also possible to perform qualitative analysis of curve line gradient in the scope of limited fatigue life (estimated line gradient is near to curve line according to experimental data +, worse situation from the point of view -). In the scope of unlimited fatigue life a quantitative analysis is possible (location of the estimated line below experimental data +, above -) as well as the quantitative revealing average percentage error. The results of analyses defined in such way presented in charts 1 and 2.

Tab. 1 Qualitative analysis of determination methods for high-cycle fatigue strength

Type of steel / state	A		B		C	
	[3]	[5]	[3]	[5]	[3]	[5]
S235JR/ in raw state	+	+	+	-	+	+
S355J0/ in raw state	+	-	+	-	+	-
15Cr2/quenched and tempered	-	+/-	+	-	-	+
34CrMo4/ normalised	+	-	+	-	+	+/-
42CrMo4/ after plastic forming	+	+/-	+	-	+	+
C40/ normalised	+	-	+	-	+	-
C45/ normalised	+	-	+	-	+	-
SAE 8630/ quenched and tempered	-	-	+	-	-	-

Legend:
A – Location of estimated curve line with respect to experimental line ($\sigma a<Re$),
(+) – below experimental line,
(-) – above experimental line,
(+/-) – crosses experimental line.
B – Gradient of part of the curve for limited fatigue life,
(+) – gradient near to experimental line gradient,
(-) – gradient noticeably different from experimental line gradient.
C – Location of fatigue limit,
(+) – below the fatigue limit of the experiment,
(-) – above the fatigue limit of the experiment,
(+/-) – fatigue limit is almost even.

Tab. 2 Value of fatigue limit – presented as a difference between experimental fatigue limit and fatigue limit calculated in MPa

Type of steel / state	[3]	[5]
S235JR/ in raw state	29,4	3,5
S355J0/ in raw state	42,1	-31,1
15Cr2/ quenched and tempered	-37,5	27,5
34CrMo4/ normalised	83,6	-0,6
42CrMo4/ after plastic forming	78,9	78,9
C40/ normalised	23,8	-21,6
C45/ normalised	33,0	-12,5
SAE 8630 /quenched and tempered	-116,3	-68,4

Data statement of the chart 1 shows specific tendency. Very noticeable is that of the column „B”, where the method described in [3] has gained the result of„+”. Conclusions on the analysis as follows.

6. Summary

Performed analysis enables to conclude the following:

- location of the estimated fatigue life line, regarding the group of materials for which the analysis were made, is more beneficial for the method according to the publication [3],
- performing the qualitative comparison of curve gradient in the scope of limited fatigue life, the performed analysis shows estimation from publication [3] as more beneficial,
- as far as estimation of fatigue life is concerned, both methods are comparable,
- in the scope of the qualitative analysis deviation of experimental, defined fatigue limit and limited fatigue life – average error values are more beneficial for the FITNET method.

It shall be stressed that the statement of data, analysis and its conclusions apply to limited group of materials. Verification shows defined tendency and indicates purposefulness to present a wider group of materials.

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