20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

HYBRID METHOD FOR DETERMINING FATIGUE CHARACTERISTIC IN HIGH CYCLE LIFE

P. Strzelecki*, J. Sempruch**

Abstract: *The paper presents hybrid method for determine fatigue S-N curve in limited life region. To invent this method, gamma distribution of slope coefficient fatigue characteristics has been estimated. From this distribution was proposed value of slope S-N curve as mode of distribution m slope for smooth and notched specimen. To verify this approach, fatigue test of smooth and notched specimen of 42CrMo4 and C45+C steel has been carried out. Qualitative verification has occurred that proposed method get better results for notched specimen and worse for smooth specimen.*

Keywords: High-cycle fatigue, Fatigue design, Accelerated methods, Hybrid methods, S-N curve.

1. Introduction

To dimensioning the new element of machine, constructor must have fatigue characteristic of material which will be used. To obtain such diagram, it should be carry out fatigue tests e.g. by standard PN H 04325:1976. These tests are expensive, long and conservative. From these reasons, analytical methods has been invented. These methods can be found e.g. in publications by Neimitz A. et al. (2008), Lee Yung-Li et al. (2005) and Strzelecki and Sempruch (2011).

In papers Strzelecki and Sempruch (2012) and Strzelecki and Sempruch (2014) have been made verification of analytical methods. In these papers have been proved that analytical methods can provide to big mistake. For this reason, hybrid (analytical-experimental) method will be presented.

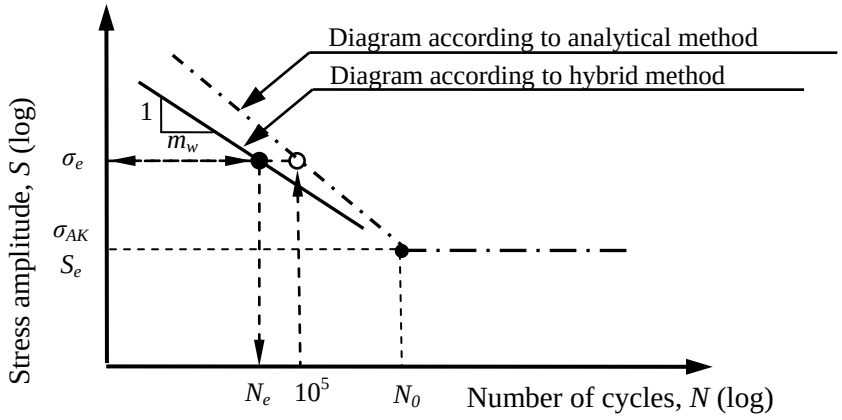

Fig. 1: Hybrid (analytical-experimental) aproach to determine line of S-N *curve for limited fatigue life.*

2. Description of Hybrid Method

Hybrid method is based on determine fatigue curve by analytical method e.g. FITNET method. First, it must be determine characteristic by analytical method. Then it is calculate value of stress amplitude (σ_e)

* M.Sc. Ing. Przemysław Strzelecki, PhD. Student: Institute of Mechanical Engineering, University of Technology and Life Sciences, 85-789 Bydgoszcz, Poland; p.strzelecki@utp.edu.pl

** Prof. Ing. Janusz Sempruch: Institute of Mechanical Engineering, University of Technology and Life Sciences, 85-789 Bydgoszcz, Poland; semjan@utp.edu.pl

for 10^5 cycles according determined characteristic. Next step is carrying out fatigue test for load equal σ_e for three specimen. After that, it is calculated mean value of got results – N_e. Now, through point with coordinate (N_e, σ_e) it is drawing line with slope m_w. On Fig. 1, the above schematic procedure was presented. Coefficient m_w is equal 10.9 for smooth specimen and 5.3 for notched specimen (structural element). These value for m_w has been obtained from gamma distribution estimated from coefficient m_a for fatigue characteristic for normal stress for smooth (91 characteristics) and notched (41 characteristics) specimen - Fig. 2. Data has taken from literature. On Fig. 2 by green point has been marked mode which equal 10.9 for smooth specimen and 5.3 for notched specimen.

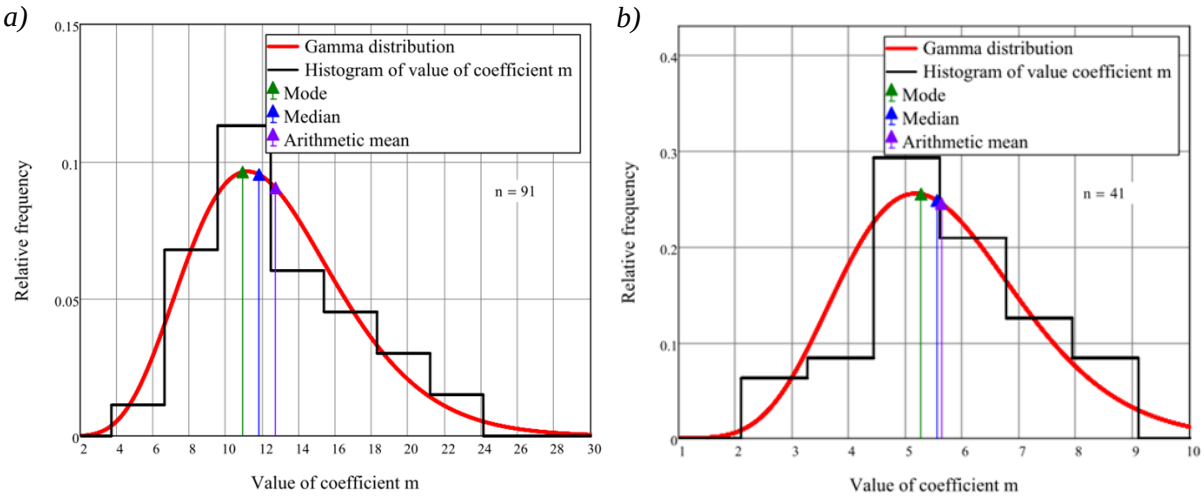

Fig. 2: Distribution of coefficient m_a for contruction steel materials for: a) Unnotched specimen; b) Notched specimen.

3. Methodology of the Experiment

To verify above method, fatigue tests of material 42CrMo4 and C45+C, were carried out. In papers Strzelecki and Sempruch (2012) and Strzelecki and Sempruch (2014) was presented the geometry of smooth and notched specimen. Machine for rotating bending was being used. In paper Strzelecki and Sempruch (2012) has been made and presented verification of this device.

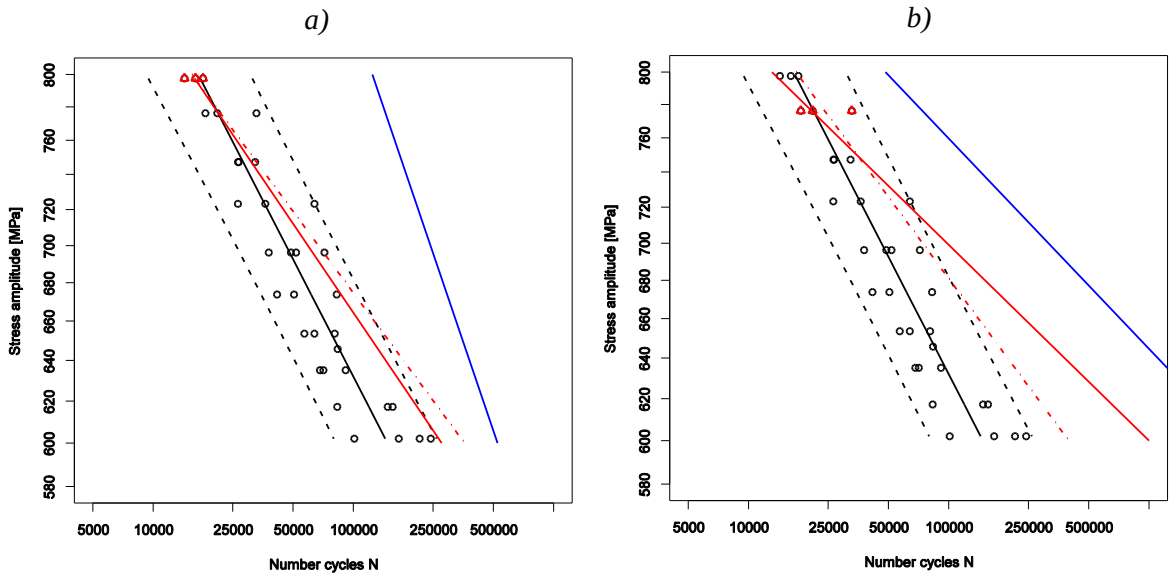

Fig. 3: S-N curve for 42CrMo4 steel for smooth specimen and characteristic according: a) FITNET method; b) Lee & Taylor method. Black line – curve estimated from experiment, blue line – according analytical method, red dot and dash line – according hybrid method, red line – through points N_e,σ_e and σ_{AK}/S_e,N_0, black dashed line – scatter band for confidence level 5%, points – results from experiment.

4. Results of Experiment and Determined Characteristics

Results of fatigue test are present on Fig. 3 to Fig. 6. Characteristics determine by analytical and hybrid method has been marked on Fig. 3 to Fig. 6. FITNET method and Lee and Taylor method has been taken to make comparison of analytical and hybrid approach.

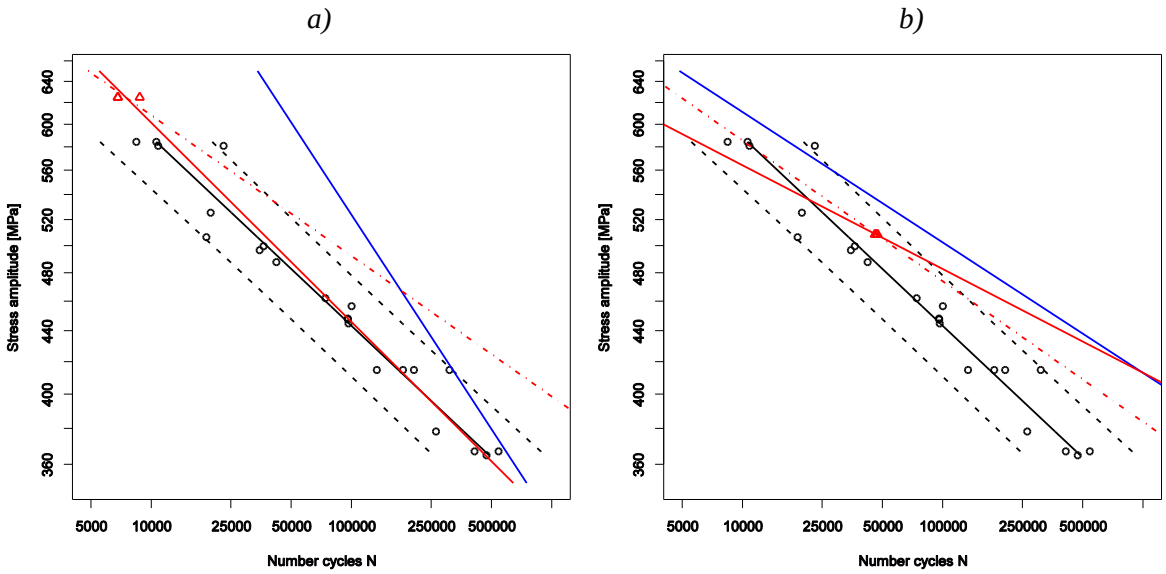

Fig. 4: S-N curve for C45+C steel for smooth specimen and characteristic according: a) FITNET method; b) Lee & Taylor method. Black line – curve estimated from experiment, blue line – according analytical method, red dot and dash line – according hybrid method, red line – through points N_e,σ_e and σ_{AK}/S_e,N_0, black dashed line – scatter band for confidence level 5%, points – results from experiment.

It must be explain that red line has been drawn through point (N_e, σ_e) and (σ_{AK}/S_e, N_0). This approach is present to show influence of determine fatigue limit and knee point on error of getting characteristic. This error will always occur went fatigue properties are determining on monotonic properties of material – ultimate strength in this case. For example, N_0 has different proposition for value presented by Sonsino (2007) and Ligaj and Szala (2013).

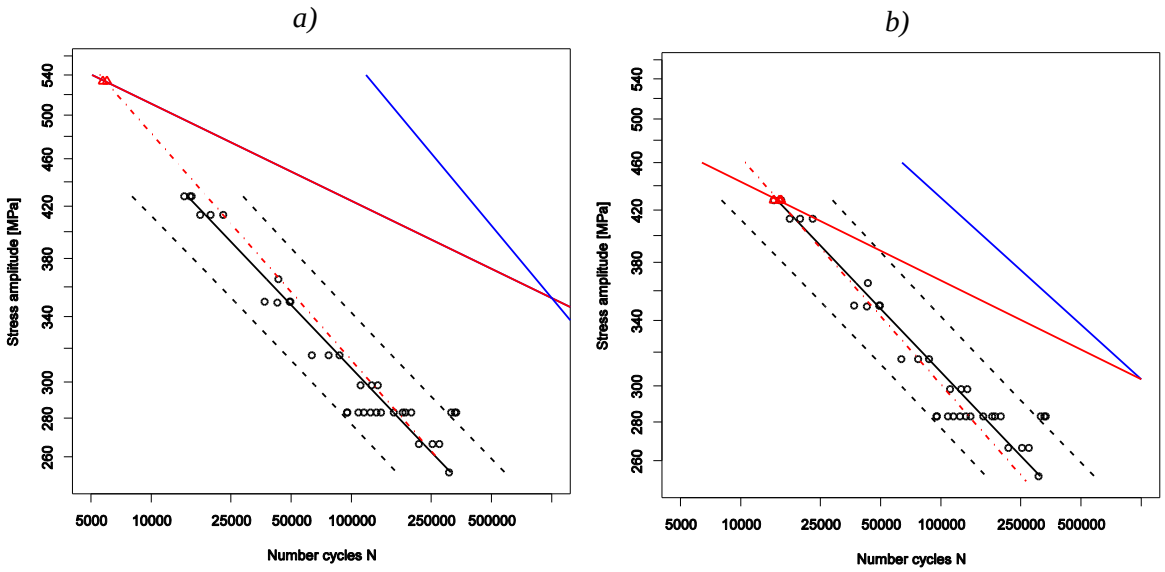

Fig. 5: S-N curve for 42CrMo4 steel for notched specimen K_t = 1.99 and characteristic according: a) FITNET method; b) Lee & Taylor method. Black line – curve estimated from experiment, blue line – according analytical method, red dot and dash line – according hybrid method, red line – through points N_e,σ_e and σ_{AK}/S_e,N_0, black dashed line – scatter band for confidence level 5%, points – results from experiment.

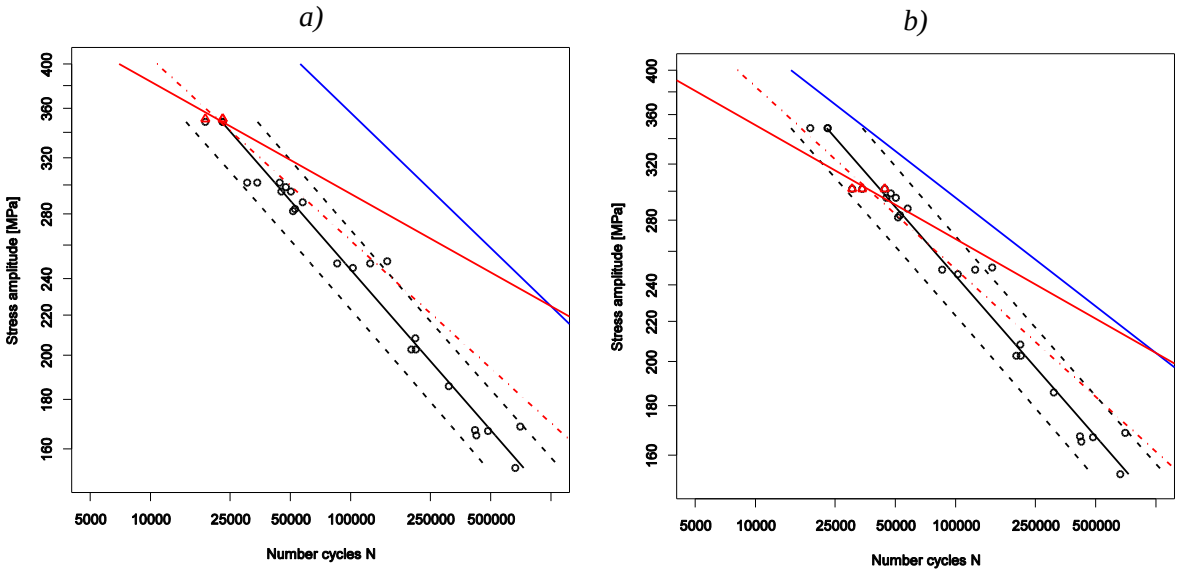

Fig. 6: S-N curve for C45+C steel for notched specimen K_t = 1.99 and characteristic according: a) FITNET method; b) Lee & Taylor method. Black line – curve estimated from experiment, blue line – according analytical method, red dot and dash line – according hybrid method, red line – through points N_e,σ_e and σ_{AK}/S_e,$N_{0,}$ black dashed line – scatter band for confidence level 5%, points – results from experiment.

5. Summary

Proposed hybrid method has been obtained better results than analytical method. On Fig. 3 to Fig. 6 was presented hybrid method with fixed slope coefficient and hybrid method for determining by two points. It is visible, that better fitting to curve estimated from experiment have hybrid method with constant coefficient. Only for smooth specimen and using FITNET method is converse.

Reference

Lee, Y.-L., Pan, J., Hathaway, R. B., Barkey, M. E. (2005) Fatigue testing and analysis, University of Alabama, Elsevier.

Ligaj, B., Szala, G. (2013) Hybrid method for calculating fatigue life (in Polish). edited by J. Szali, Bydgoszcz ITE.

Neimitz, A., Dzioba, I., Graba, M., Okrajni, J. (2008) Evaluation of strength, life and safety of structural components contain defects. Politechnika Świętokrzyska, Kielce.

PN-H-04325:1976, Test of metal fatigue - Basic terms and general guidelines for preparing of samples and carry out tests.

Sempruch, J., Strzelecki, P. (2011) Error of fatigue life determination according to the FITNET method. In: Proc. 17th International Conference Engineering Mechanics, (V. Fuis, edt.), Svratka, Czech Republic, pp. 531-534.

Sonsino, S. M. (2007) Course of SN-curves especially in the high-cycle fatigue regime with regard to component design and safety. International Journal of Fatigue, Vol. 29, No. 12, pp. 2246-2258.

Strzelecki, P., Sempruch, J. (2012) Experimental Verification of the Analytical Method for Estimated S-N Curve in Limited Fatigue Life, Materials Science Forum, Vol. 726, pp. 11-16.

Strzelecki, P., Sempruch, J. (2011) Modification of selected methods of rapid determination of fatigue characteristics in the range of limited fatigue life, Journal of Polish Cimac Selected problems of designing and operating technical systems Vol. 6, No. 3; pp. 289.

Strzelecki, P., Sempruch, J. (2014) Experimental Verification of Analytical Method for Determining the S-N Curve Alloy Steel, Key Engineering Materials, Vol. 598, pp. 219-224.