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METHODOLOGY FOR DETERMINING THE REGION OF STABILIZATION OF LOW-CYCLE FATIGUE

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Abstract: In present paper, the behaviour of high-strength low-alloyed (HSLA) steel under conditions of low-cycle fatigue (LCF) has been experimentally tested and analyzed. Based on the experimental results obtained in the programme EXCEL, characteristic regions of low-cycle fatigue of steel NIONIKRAL 70 (NN-70) have been determined, the most important being the region of stable behaviour of materials, so-called "the region of stabilization". From this region, on the basis of pre-defined requirements, characteristic stabilized hysteresis have been isolated for each strain level, based on which the indicators of low-cycle fatigue of steel NN-70 have been identified.

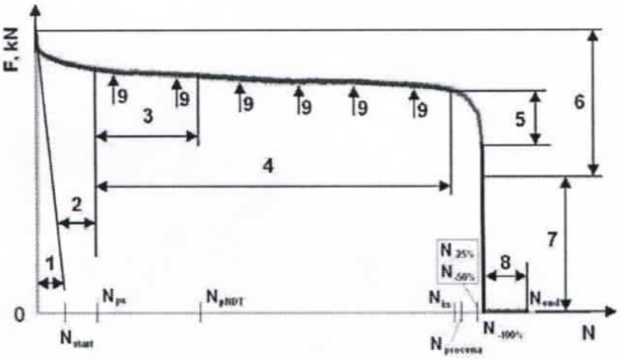
Keywords: HSLA steel, LCF, the region of stabilization, stabilized hysteresis

1. Introduction

Steel, NN-70, selected in this study to investigate the experimental behaviour affected by fatigue loading, among other things, is used in shipbuilding and for manufacture of pressure vessels as well. The experiment was conducted using smooth round specimens made of steel NN-70 as parent metal (PM). When selecting stabilized hysteresis as a representative of all of stabilized hysteresis for one strain level, and for the further processing of low-cycle fatigue test results, the recommendations of standards [1, 2] have been used as well as the methodology based on which linearity of the stabilization regions of low-cycle fatigue was numerically determined [3].

2. Numerical determination of the region of stabilization

Most of the materials, at low-cycle fatigue and at a certain level regulated strain, achieve a so-called stabilized condition. It is a condition when the height of the hysteresis loop expressed through a range of force of loading or stress slightly changes, Fig. 1.



1 – Adjustment of tearing machine;
2 – Adaptation of tearing machine, tools and specimen;
3 – Crack formation up to threshold of NDT;
4 – **Stabilized state;**
5 – Force drop of 25 % (ISO 12106:2003(E)) [1];
6 – Force drop of 50 % (ASTM E 606-04) [2];
7 – Force drop to F=0;
8 – Stoppage of tearing machine;
9 – Height of hysteresis loop;
N_{start} - Test start up, **F=max;**
N_{ps} - Beginning of stabilization;;
N_{pNDT} – threshold of NDT;
N_{ks} – End of stabilization; $N_{xx\%}$ - force drop of xx %;
$N_{procena}$ – force-drop assessment of an operater;
N_{end} – Test termination.

Fig. 1. Regions of low-cycle fatigue

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The most common methods for determination of the number of cycles to crack initiation, N_f, are defined by the standards [1, 2]. New methods [3] for determination of the beginning and end of the crack initiation and establishment of linearity of stabilization regions are based on experimental data, by arbitrary selection of three cycles on the basis of which we can establish linearity that we maintain by filtering the data in the programme EXCEL, toward the beginning and end of the test. In this way we determine the initial, N_{ps}, and final, N_{ks}, cycle of stabilization, i.e. the beginning and end of the crack initiation, Fig. 1. Stabilized hysteresis, N_{s1}, is located in the middle of the region 9, Fig. 1, and is determined by the formula, $N_{s1}=N_{ps}+(N_{ks}-N_{ps})/2$.

This method of determination of the stabilized hysteresis, N_{s1}, is called "Method of the middle stabilization" [3]. In a similar way, we can establish a cycle of appearance of a crack of 1 mm^2 surface area [4], which can be identified by the NDT methods, which is called the "threshold NDT method" [3], and then the cycle of stabilized hysteresis, N_{s2}, which is located in the middle of the region 3, Fig. 1, so that $N_{s2} = N_{ps}+(N_{pNDT}-N_{ps})/2$. This procedure was applied to other specimens as well, i.e. other strain levels, $\Delta\varepsilon/2=0.35$, 0.50, 0.60, 0.70 i 0.80. After processing of registered data from all stabilized hysteresis of interest obtained using the methodology described, the curves of low-cycle fatigue for steel NN-70 are defined:

1. **Cyclic stress-strain curves,** $\frac{\Delta\varepsilon}{2}=\frac{\Delta\sigma}{2E}+\left(\frac{\Delta\sigma}{2K'}\right)^{\frac{1}{n'}}$:

for $\underline{N_{s1}}$: $\frac{\Delta\varepsilon}{2}=\frac{1}{221378}\cdot\frac{\Delta\sigma}{2}+\left(\frac{1}{946.2}\cdot\frac{\Delta\sigma}{2}\right)^{\frac{1}{0.047}}$, for $\underline{N_{s2}}$: $\frac{\Delta\varepsilon}{2}=\frac{1}{221378}\cdot\frac{\Delta\sigma}{2}+\left(\frac{1}{887.2}\cdot\frac{\Delta\sigma}{2}\right)^{\frac{1}{0.032}}$ and

2. **Basic curves of low-cycle fatigue,** $\frac{\Delta\varepsilon}{2}=\frac{\sigma_f'}{E}N_f^b+\varepsilon_f' N_f^c$:

for $\underline{N_{s1}}$: $\frac{\Delta\varepsilon}{2}=0.005105\cdot N_f^{-0.061}+0.0612\cdot N_f^{-0.564}$, for $\underline{N_{s2}}$: $\frac{\Delta\varepsilon}{2}=0.005117\cdot N_f^{-0.065}+0.0881\cdot N_f^{-0.695}$

3. Conclusions

The results of experimental investigation have given us important information about the understanding of fatigue behaviour of HSLA steel, NN-70, and the newly applied methods and recommendations of standards as well have enabled the precise determination of characteristic stabilized hysteresis for each strain level. From certain characteristic stabilized hysteresis, based on defined criteria, the data necessary for determination of the equations of characteristic curves of low-cycle fatigue have been collected, which show the difference between the values of exponents and coefficients defined by presented methodology depending on the method applied for the determination of stabilized hysteresis.

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References

[1] ISO 12106:2003(E): Metallic materials-fatigue testing-axial-strain-controlled method, Geneva: ISO 2003, Switzerland.
[2] ASTM E606-04, Standard practice for strain-controlled fatigue testing, ASTM International, West Conshohocken, Pennsylvania, USA.
[3] Aleksić Vujadin: Niskociklični zamor niskolegiranih čelika povišene čvrstoće, Radna verzija prijavljene doktorske disertacije, Univerzitet u Beogradu, Tehnološko-metalurški fakultet, Beograd, 2016.
[4] Janković D. M., Malociklusni zamor, Univerzitet u Beogradu, Mašinski fakultet, Beograd, 2001.

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