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Monitoring of fatigue damage development in as-received and exploited 10CrMo9-10 power engineering steel supported by Digital Image Correlation

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1. Introduction

Damage development in power engineering steel structures requires instant monitoring to maintain their properties, ensure the safety of working components and estimate their service life. One should highlight, that the operational loads and simultaneous microstructural changes occurring due to high-temperature exposure accelerate the development of damage dynamics significantly. Thus, it is of the highest importance to maintain the safe state of power engineering steel pipes subjected to continuous operations under high pressure and temperature to further minimize the operating costs of industrial structures. Therefore, the main goal of this research is to assess and describe the effect of 280 000 h operating conditions on the microstructure, strength properties and dynamics of fatigue damage development of 10CrMo9-10 power engineering steel (10H2M). The quantitative assessment of the degradation state in 10H2M steel was described as a function of the fatigue damage measure, φ, and the fatigue damage parameter D.

2. Methods

Firstly, standard tensile tests at the strain rate equal to $2\times10^{-4}s^{-1}$ were performed to assess the mechanical properties of both states of 10H2M steel. Based on these tests and mechanical parameters determined, fatigue loading conditions were established. Both uniaxial tensile and fatigue tests were executed on the MTS 858 testing machine. The fatigue tests were force controlled with pulsating from zero level and a constant stress amplitude with a frequency of 20 Hz in the range of stress amplitude from 330 MPa to 430 MPa. The fatigue development was monitored by DIC Aramis 12M.

3. Results

The fatigue tests performed on the as-received and exploited steel revealed notable differences in mechanical response. The exploited material tested at the same stress amplitude was able to transfer only half of the number of cycles in comparison to the as-received material. Depending on the stress amplitude, the fatigue lifetime of the exploited material decreased from 300% to 400%. The representative images of strain distribution for both types of steel in question are also presented, and subsequently, compared for two stress amplitudes of 400 MPa and 350 MPa.

4. Conclusions

Comparison of the mechanical response of the as-received and exploited 10H2M steel revealed a drastic decrease of the fatigue lifetime of up to 400% after 280 000 hours of exploitation at the industrial working conditions represented by the temperature of 540°C and internal pressure of 2.9 MPa. The dynamics of the fatigue damage development for both states of steel were successfully monitored by DIC system and quantitatively well assessed using the fatigue damage measure ϕ, and fatigue damage parameter D.