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EVALUATION OF FATIGUE DAMAGE DEVELOPMENT IN POWER ENGINEERING STEEL AFTER LONG TIME EXPLOITATION SUPPORTED BY DIC TECHNIQUE

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1. Introduction

The exploitation loads and associated with them microstructural changes occurring due to high-temperature exposure significantly accelerate the development of damage dynamics [1]. Thus, this research aimed to compare the behaviour of long-time degradation of 10CrMo9-10 (10H2M) power plant steel to that of the same material in the as-received state by using different experimental and analytical approaches. The specimens machined from the as-received steel and the same material after exploitation for 280 000h at the temperature of 540°C were subjected to fatigue that was simultaneously monitored by means of the Digital Image Correlation (DIC) technique.

2. Materials and methods

The fatigue testing was performed on wire-cut specimens made of the 10H2M steel pipe in the as-received and exploited states (280 000h at the temperature of 540°C and internal pressure of 2.9 MPa).The standard tensile tests were firstly carried out at the strain rate equal to 2×10^{-4} s^{-1} in order to assess the mechanical properties of both states of the steel considered. Fatigue loading conditions were established based on these tests and mechanical parameters examined. Both, uniaxial tensile and fatigue tests were executed on the MTS 858 testing machine. The fatigue tests were stress controlled with (σ_{max}- σ_{min})/2 mean stress level and stress asymmetry coefficient R=0, frequency of 20 Hz, and stress amplitude in the range from 330 MPa to 430 MPa. The range of fatigue stress amplitude values was established based on the conventional yield strength $R_{0.2}$ determined on the basis of the uniaxial tensile test. The strain values necessary for the hysteresis loop determination were recorded by the conventional MTS extensometer with a gauge length of 25 mm. The fatigue development was monitored by DIC Aramis 12M equipped with lenses of a total focal length of 75 mm and calibration settings appropriate to the measuring area equal to 170x156 mm. The calibration was performed before tests using a certified GOM calibration plate. Aramis software enabled to capture DIC images automatically at σ_{max} after each of 1000 fatigue cycles.

3. Results and conclusions

The fatigue tests carried out on both material types 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 one. Depending on the stress amplitude, the fatigue lifetime of the exploited material decreased from 300% to 400%. Long-term service leads to a significant decrease in the fatigue life of pipes and degradation of properties is mostly attributed to the accumulation of defects in the material during operation [2-3]. The fatigue damage development was monitored during fatigue by using DIC technique. The representative images of strain distribution for both types of steel in question were presented, and subsequently, compared for the

stress amplitude equal to 400 MPa, Fig. 1. Since the specimen geometry enforces a damage to be developed in its middle section, the effective gauge for DIC observations was significantly reduced after initial tests, as could be observed in Figure 1a-b. It should be highlighted, that at the higher stress amplitude considered, the strain recordings from the specimen surface were as high as 18%, thus, the unified strain scale was inconvenient to apply. It is easy to see, that a different strain distributions were found for both states of the material, and as a consequence, the fatigue lifetime of the exploited material was about two times lower than that of the as-received one. It should be mentioned, that for the exploited material, the significant changes in strain distribution, reflecting damage development, were found in the middle section of the specimen when half of its fatigue life was reached, Fig.1a. Subsequent cycles led to the continuous development of damage in the central region of the specimen and its failure after 2.1×10^5 cycles. On the other hand, the as-received specimen exhibited damage localization shortly before the failure as the first strain concertation area was found after 5×10^5 cycles and the specimen fractured after 5.5×10^5 cycles, Fig.1b.
Comparison of the DIC images for the material in as-received state to those obtained for the exploited one clearly identifies differences in damage mechanisms. The results clearly indicate, that DIC is a powerful tool for strain localization analysis during fatigue and identification of damage mechanisms, especially at higher magnitudes of stress amplitude.

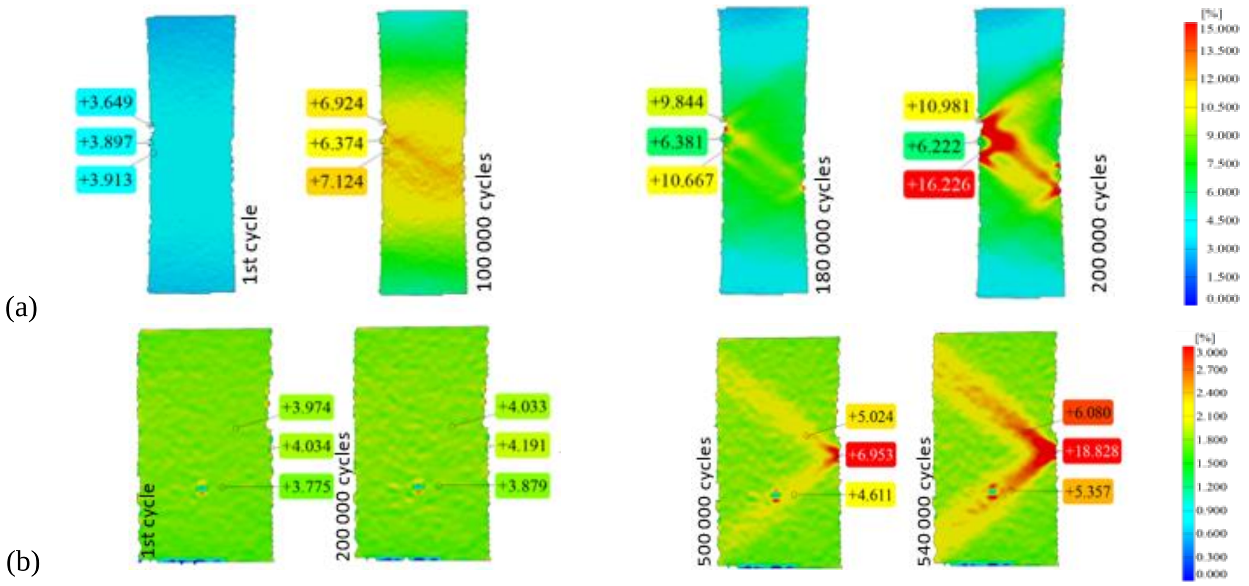

Fig. 3. DIC measurements performed on the exploited (a) and as-received (b) material for the stress amplitude equal to 400 MPa.

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5. References

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