MATEC Web of Conferences **12**, 06004 (2014)
DOI: 10.1051/matecconf/20141206004

Fatigue damage monitoring in 304L steel specimens by an acoustic emission method

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Abstract. The aim of this work was to clarify fatigue crack initiation and propagation mechanisms in 304L austenitic stainless steel under different total-strain-amplitudes. A complete process from crack initiation and propagation was recorded by using the acoustic emission method in one hand, and replica method in another hand. The effect of strain amplitude on fatigue crack growth was investigated and a new representation of various fatigue curves associated to various levels of fatigue damage is proposed.

Austenitic stainless steels are widely used in Nuclear Power Plants (NPPs), especially in the primary circuit. There material is then subjected to thermo-mechanical cycling caused by temperature gradients during start-ups, shutdowns or operating transients. Consequently, Low Cycle Fatigue (LCF) is considered as one of the main failure mechanisms being able to affect NPPs life [1].

Fatigue design in nuclear industry has been based for decades on reference curves obtained from usual laboratory fatigue tests on small specimens. It is worth noting that, in the framework of experimental campaigns, the conventional numbers of cycles to rupture of these tests include several steps related to various damage mechanisms: plasticity activity leading to crack initiation at a microscopic scale, then crack growth at a microscopic scale and finally rupture of the fatigue specimen caused by crack growth at a macroscopic scale. Nowadays, to continue to make safer the design of austenitic stainless steel nuclear components, industrial methods require a better understanding of each of these damage mechanisms.

To do that, LCF tests are conducted on a servo-hydraulic machine (MTS 810) at different total-strain-amplitudes ranging from +/-0.6% to +/-0.2%, in laboratory air and at room temperature. The input strain signal was triangular in shape. The basic characterization was based on the results of tests conducted with a constant strain rate of 10^{-3} s^{-1} and a strain ratio $R_{\varepsilon} = \varepsilon_{min} / \varepsilon_{max} = -1$. The test specimens used are cylindrical with a gauge section of 8 mm in diameter, 22 mm in length and a total length of 135 mm. To minimize the effects of the surface irregularities on fatigue lives, a final surface preparation is achieved. The material used in this study is an AISI type 304L austenitic stainless steel, its chemical composition, microstructure and cyclic stress-strain behavior at different total-strain-amplitudes have been already described elsewhere [2].

To study damage in this material under these conditions, an Acoustic Emission (AE) method is firstly used. Detection and analysis of AE are powerful means for identification of damage phenomena and monitoring of their evolution. The characteristics of different AE sources were studied by multivariate statistical acoustic signals. Based on k-means cluster algorithm, different AE

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sources are classified. And the results indicate that the AE characteristics of different AE sources, such as plastic deformation, cracking and martensitic transformation, differ significantly [2]. The results allow to clearly observing the damage sequence with the corresponding numbers of cycles.

Here, we focused only on the stage of initiation and propagation of cracks. Figure 1 shows the cumulated AE energy of acoustic signals identified by the pattern recognition method of cracks activity, versus the number of cycles at different total-strain-amplitudes.

However, with regard to damage quantification, usual experimental techniques as replica examination still remain the better way to obtain, for instance, surface length of the fatigue crack. Thus kinetics of micro crack initiation, micro crack propagation and macro crack propagation may be highlighted. Figure 2 shows the evolution of main cracks versus the number of cycles at different total-strain-amplitudes.

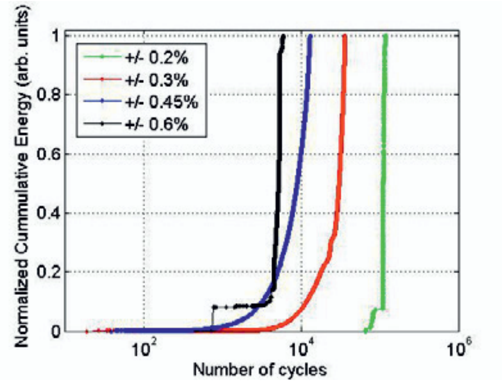

Figure 1. Evolution of acoustic signal energy.

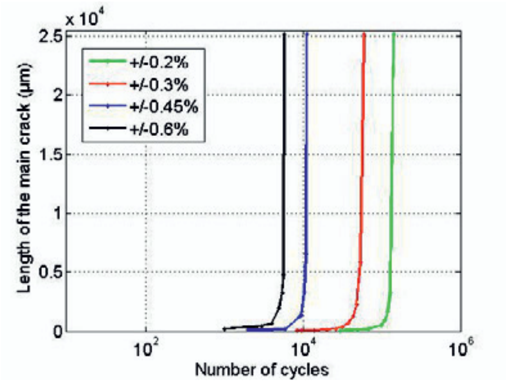

Figure 2. Evolution of the main cracks.

In conclusion, 304L LCF was monitored by AE, in one hand, and by replica method, in the other hand, for different total strain amplitudes. The evolution of acoustic signals of cracks activity identified by the pattern recognition method is in good agreement with the quantification of the damage obtained by the replica method. Finally, by performing such kind of analyses, it is here proposed to plot various fatigue curves associated to various levels of fatigue damage (Fig. 3).

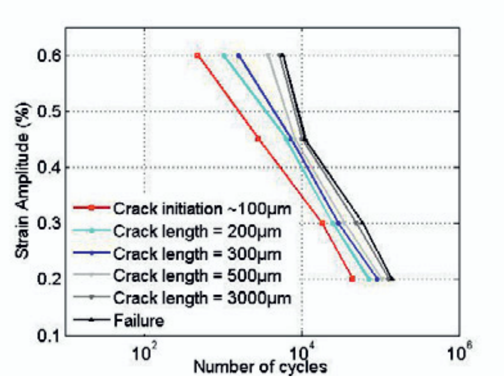

Figure 3. Fatigue reference curves associated to various levels of fatigue damage.

References

1. L. De Baglion, J. Mendez, Procedia Engineering **2** (2010)
2. A. Ould Amer, A-L. Gloanec , S. Courtin , C. Touzé, Procedia Engineering **66** (2013)