Changes in Lattice-Strain Profiles around a Fatigue Crack through the Retardation Period after Overloading

Y. Sun[a], K. An[b], F. Tang[b], C. R. Hubbard[b], Y. L. Lu[a], H. Choo[a,b], and P. K. Liaw[a],

a Materials Science and Engineering Department, The University of Tennessee, Knoxville, TN 37996.

b Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

Introduction

•After overload, there is a period of crack-growth retardation that is related to the magnitude and number of overloads.

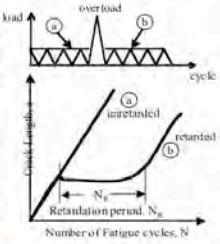
•The retardation of the crack-growth behavior can be understood in the context of the plasticity-induced crack-closure mechanism.

Scientific Issues

•Investigate the overload effect. The results will provide a fundamental understanding of the damage process that takes place at the crack tip.

•Improve the fatigue life of the material, which can help to develop a new material with a better crack resistance.

•Using neutron diffraction to map the elastic/plastic strains in front of the crack tip, which can help us in the micro-mechanical modeling effort.



Material

Type 316 stainless steel (SS) has been widely used in the nuclear industry, because of its excellent ductility, corrosion resistance, and irradiation performance.

•Yield strength is 288 MPa

•Young's modulus, E, is 178 GPa

•Poison's ratio is 0.33

•The grain size is about 50 μm.

Experiments

Fatigue Experiments

•Precrack: The compact tension (CT) specimens were precracked to approximately 12.7 mm. The final ΔK used during precracking was 20 MPa.

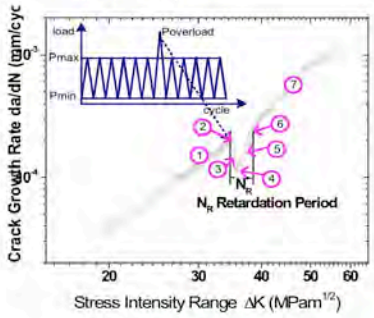
•Load-controlled high-cycle fatigue:

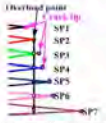
➢Seven CT specimens were fatigue tested

➢Applied load range ΔP controlled Pmax = 9,880 N, Pmin = 988 N

➢R ratio of 0.1 (R =σmin./σmax., where σmin. and σmax. are the applied minimum and maximum stresses, respectively.

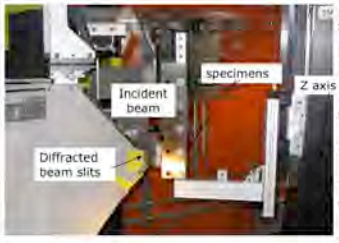
➢Overload was applied during the fatigue test when the crack length was 15.29 mm (See below).





SP	CL(mm)
SP1	13
SP2	15.3
SP3	15.6
SP4	16.3
SP5	17
SP6	17.9
SP7	25.3

Neutron Experiments



Neutron-diffraction transverse strain measurements were performed using the NRSF2 instrument at the High Flux Isotope Reactor (HFIR) of the Oak Ridge National Laboratory

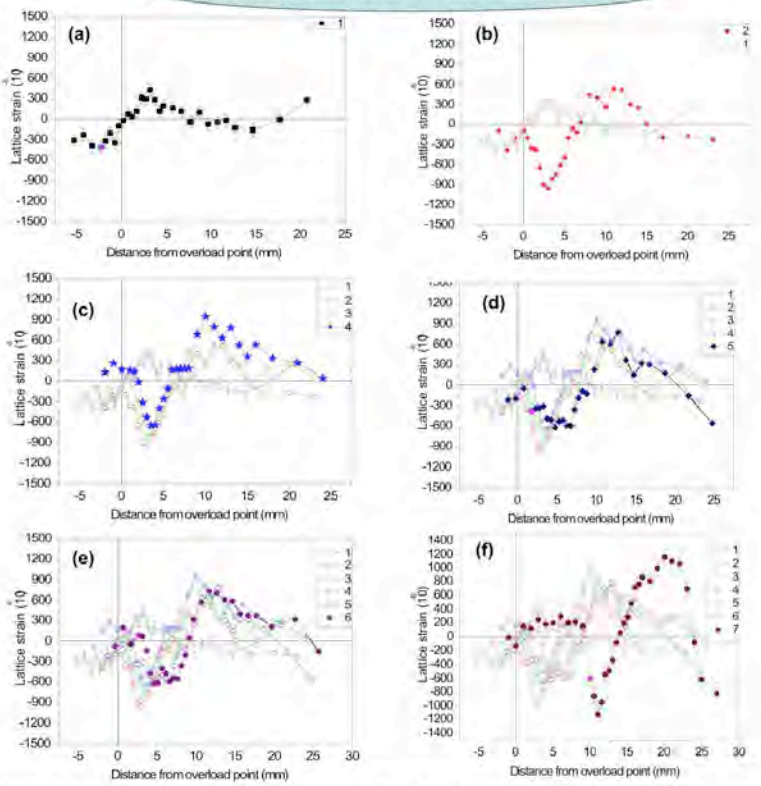
•Wavelength was 1.73 Å

•(311) reflection of 316SS was used for determining strain

•Gage volume was 1 x 2 x 2 mm^3

Results and Discussion

Evolution of the Lattice Strain Profiles around the Crack Tip

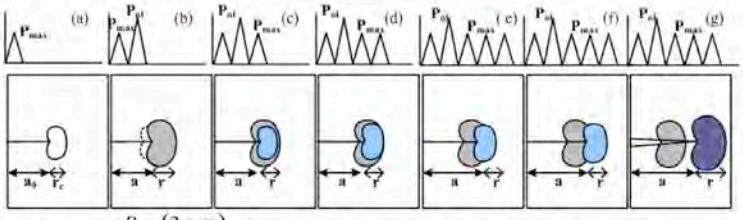


•Large compressive region in front of the crack tip was observed in *SP2* strain profile.

•The strain profile of *SP3* and *SP4* is quite similar to that of *SP2*

•*SP5* and *SP6*, there are two peaks in the compressive strain profile.

Perturbed Plastic Zone



$$K_{max} = \frac{P_{max}(2+\alpha)}{B\sqrt{W}(1-\alpha)^{3/2}}\left(0.886+4.64\,\alpha-13.32\,\alpha^2+14.72\,\alpha^3-5.6\,\alpha^4\right)$$

Stress intensity factor K: P is the applied load; $\alpha = a/W$; *a* is the total crack length; W is the specimen width; B is the specimen thickness.

Results

•The overload produced a large plastic deformation, which, in turn, led to a dramatic decrease in the crack-growth rates.

•SP2, 3 and 4: the increase in the crack length is too small to go through the plastic zone created by the overload,

•SP5 and 6: The first peak is due to the large plastic zone created by the overload, and the second peak is caused by the subsequent fatigue cycles,

•As the crack grew longer and out of the overload-perturbed region during the subsequent fatigue deformation, the crack-growth rates recovered to the original slope.

Acknowledgements

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