1 Analysis and Interpretation of Creep-Fatigue Crack Growth Behaviour

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1 Introduction

Life extension of the UK’s advanced gas cooled reactors (AGRs) is dependent on the assurance of the safety of their structural components. As many AGR components operate in the creep range, it is important to understand and to be able to predict creep and creep-fatigue crack growth for real or postulated defects in these components. The R5 Volume 4/5 procedure gives advice on the prediction of creep and creep-fatigue crack growth of defects in components operating in the creep range. In order to predict crack growth behaviour using this advice, it is necessary to use appropriate crack growth properties obtained from suitable laboratory test specimens. In most cases, the crack growth properties are obtained by testing high constraint Compact Tension, C(T), specimens. Whilst creep-fatigue crack growth is generally predicted by a simple summation of creep and (continuous cycling) fatigue crack growth, there are some situations where creep-fatigue interaction is significant and it is necessary to use data obtained from creep-fatigue crack growth tests. However, interpretation of data from these tests implicitly assumes that crack propagation is continuous, although it is now accepted that crack growth at high temperatures is often discontinuous.

The main aim of this work is to develop improved methods for interpreting crack growth data in creep-fatigue tests for situations where cracking is discontinuous. This will be achieved by using a combination of novel experimental techniques and study methods.

1.1 Previous Research

A number of creep-fatigue crack growth tests have been carried out previously by Imperial College and EDF Energy on Type 316H and other materials using C(T) specimens. Direct current potential drop (DCPD) techniques have generally been used to monitor crack growth in these tests and to distinguish between crack growth occurring during the creep dwell and during the fatigue part of the cycle. However, recent work on creep crack growth (including K Tarnowski’s PhD studies) has shown that the DCPD response is also influenced by crack morphology (continuous or discontinuous) and by separation of the PD leads as the test specimen deforms.
2 PhD Project Plan

The main aim of this work is to investigate whether improved methods for interpreting crack growth data in creep-fatigue tests can be developed for situations where cracking is discontinuous. Potential improvements in the interpretation of crack growth data from creep-fatigue tests can be investigated by re-visiting data from relevant completed tests and by conducting a programme of new tests specifically focused on improving understanding of creep-fatigue crack growth behaviour.

2.1 Experimental Analyses

One of the major opportunities in this research is to understand how fatigue loading interacts with the growth of discontinuous intergranular cracks that form during constant load creep dwells. Previous work has used DCPD techniques to monitor crack growth in test specimens and to distinguish between crack growth occurring during the creep dwells and during fatigue cycles. However, it is believed that when fatigue cycling is applied to a specimen containing a discontinuous creep crack, this can result in ligaments of sound material connecting the crack faces behind the crack tip location being broken, resulting in a significant change in PD signal, which could be misinterpreted as a significant crack growth increment occurring during the fatigue cycle. This would also result in the crack growth increment that occurs during the creep dwell being underestimated. Novel experimental techniques that can be explored in this project include the potential use of tomography to characterise the changes in crack morphology (degree of crack discontinuity) that occur during creep-fatigue crack growth tests.

Further creep-fatigue crack growth tests will also be performed on Type 316H C(T) test specimens to augment the information that is already available from tests carried out previously by Imperial College and EDF Energy. The creep-fatigue crack growth test results will be analysed taking account of an improved understanding of the role of changes in crack morphology (degree of crack discontinuity) that occur during creep-fatigue crack growth tests in discovering the relative contributions to the overall crack growth of dwell periods and fatigue cycles.

2.2 Interpretation of Creep Crack Growth Tests

The existing creep-fatigue testing standard (including ASTM E2760) will be critically examined to investigate its suitability for interpreting data obtained from previous and new creep-fatigue crack growth tests on Type 316H C(T) specimens. It is expected that results will enable improvements to be made in interpreting data from creep-fatigue crack growth tests.