University of Nottingham
School of Mechanical, Materials, Manufacturing Engineering & Management

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Report Title:	Post-Workshop Report on Durability & Life Extension Seventh FENET-DLE Workshop "**Finite Element Issues Related To Creep And Viscoelasticity"** **25-26 March 2004, Majorca, Spain**
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1. Introduction

Under the FENET technology theme of Durability and Life Extension (DLE), 6 workshops have been launched to date:

- First DLE Workshop: "Industrial Views on Durability and Life Extension Issues"
  (13 November 2001, Wiesbaden, Germany)

- Second DLE Workshop: "Finite Element Simulation of Contact Problems"
  (27-28 February 2002, Copenhagen, Denmark)

- Third DLE Workshop: "FE issues related to Structural Integrity-Fracture, Fatigue, and Creep"
  (13-14 June 2002, Zurich, Switzerland)

- Fourth DLE Workshop: "Finite element simulation of fracture and crack growth"
  (11-12 September 2002, Trieste, Italy)

- Fifth DLE Workshop: "Finite Element Simulation of Welds and Joints"
  (27-28 February 2003, Barcelona, Spain)

- Sixth FENET-DLE Workshop: "Modelling Fatigue of Metals"
  (9-10 October 2003, Noordwijk, The Netherlands)

Discussions in previous DLE workshops have identified the analysis of creep and viscoelasticity as an important issue across many industry sectors, and have highlighted several difficulties in modelling the real-life behaviour of components operating under elevated temperatures. This DLE workshop aims to provide a forum for discussion of the issues relevant to the FE analysis of creep and viscoelasticity.

2. Workshop Objectives

The main objectives of this workshop are:

- To provide an overview of the current state of FE technology in applications related to creep, viscoelasticity and high temperature applications

- To identify current limitations and difficulties in modelling real-life creep behaviour

- To provide a forum for discussion of "Guidelines" and "Best Practice" on using FE in creep and high temperature applications

- To present current techniques for modelling creep damage, crack growth and creep life estimation

3. List of Presentations

A total of 5 technical presentations were delivered in this workshop. Presenters represented university research groups, industry and FE software vendors. Abstracts of the presentations are shown in Appendix A.

The following is a list of the technical presentations:

- "FENET-DLE Workshops - Introduction and Objectives"
  Prof. Adib Becker, University of Nottingham, UK

- "Development of a New Material Model for Polymer-Bonded Materials – An Overview"
  Dr G.S. Kalsi, AWE, Aldermaston, UK

- "Modelling Creep of Lead in Water Pipe Joints"
  Malcolm Toft, Advanced Engineering Solutions Ltd, UK

- "Creep Simulations with ABAQUS: Super Plastic Forming"
  Jose L. San-Vicente, PRINCIPIA, Spain

- "FE Analysis of Creep of welds - Challenges and Difficulties"
  Prof. Adib Becker, University of Nottingham, UK

4. Analysis of Workshop

The workshop was chaired by Professor Adib Becker (University of Nottingham, UK). The main topics covered in this workshop included the following:

- Modelling viscoelastic polymer-bonded materials
- Creep stress relaxation and healing effects
- Creep of lead pipes at low temperatures
- Modelling creep associated with superplastic forming of aerospace components
- Robustness of FE software in modelling high temperature manufacturing processes
- Difficulties in generating creep material properties
- FE modelling of creep of welds
- Incorporating creep continuum damage in FE software
- Benchmarks for creep damage modelling
- Creep-fatigue interaction

Discussions were invited after each presentation, with a final open discussion session held after the last presentation. The workshop raised many issues related to creep of metals and polymers and stimulated a number of discussions on the current state and limitations of commercial FE software.

5. Concluding Remarks

- Reliable creep material properties are not easy to obtain
- The creep material properties of narrow Heat-Affected Zones in welds are particularly difficult to obtain in laboratory tests.
- Effects of ageing/degradation of the material are difficult to measure
- To predict creep failure, it is important to understand the creep failure mechanisms of the material
- User-subroutines are often needed to model creep material laws
- Creep constants are often very small, e.g. of the order 10^{-40}
- Creep continuum damage is not easily incorporated in commercial FE codes
- FE benchmarks for creep continuum damage mechanics are useful in assessing the accuracy of FE software.

Appendix A
Summaries of Workshop Presentations

Development of a New Material Model for Polymer-Bonded Materials – An Overview
Dr GS Kalsi, AWE, Aldermaston, UK

Most Polymer-Bonded Materials (PBMs) are dual-phase composites consisting of a crystalline filler material bonded in an elastically softer polymer matrix, making for a very complex heterogeneous material. Materials such as these exhibit complex behavioural responses and it can be of critical importance to model such responses accurately.

Amongst other peculiar features, some PBMs have different Young's modulii and strengths in tension and compression, and display progressive degradation of properties under load. They can be highly strain-rate and temperature-dependent, and their properties can change with age. They exhibit stress relaxation and creep behaviour, even over very short periods of time

This presentation describes a viscoelastic material model which is currently being developed to simulate such complicated constitutive responses, including the effects of progressive damage. The progress made to date is described, as well as the difficulties in obtaining material constants.

Modelling lead creep in water pipe joints
Malcolm Toft, Advanced Engineering Solutions Ltd, Northumberland, UK

In addition to the relatively well-known problems of high-temperature creep in high-specification applications such as aerospace and power generation, there are various other areas in which creep is of interest. One of these is the use of lead for sealing joints in grey iron water pipe, and the American Water Works Association Research Foundation have funded some investigation of this as part of developing techniques for the condition assessment of joints in water distribution pipelines. This presentation discusses some of the issues raised in attempting to model lead sealant behaviour, such as problem specification, material data, choice of creep model, interaction of creep with other changes in loading, geometry and material, and the assessment and significance of results.

Creep Simulations with ABAQUS: Super Plastic Forming
Jose L. San-Vicente, PRINCIPIA, Spain

Viscoplastic strains may be dominant in metallic components at high temperature when subjected to external forces. Creep is not always an undesirable effect, but can be used in some industrial applications. This is the case for some aerospace components, where complex geometries must be sheet-formed with aluminum alloys. These materials exhibit superplastic behavior in certain temperature range and strain rates. In the manufacturing process, pressure is applied on one side of the sheet that is formed against a die. The pressure cycle is to be applied as fast as possible, for productivity reasons. However, the superplastic range is limited to a rate interval and excessive strain rate may lead to the sheet tiring. Therefore, there is interest in the optimization this production cycle. Finite element simulations may help the manufacturer in this optimization process. Nevertheless, the loads are not know a priori, but must be adaptively modified to preserve the strain rate of the material in the desired range. PRINCIPIA has experience in this kind of SPF analysis with ABAQUS. Some examples are shown in the presentation.

FE Analysis of Creep of Welds and Weld Repairs - Strategies and Difficulties

A.A. Becker, T.H. Hyde and W. Sun, University of Nottingham, UK

Finite Element simulation of the creep of welds requires a reliable set of creep material properties for at least three material zones; the parent material, weld metal and heat-affected-zone (HAZ). Two main types of material behaviour models are often used in the FE modelling; simple power law creep constitutive laws and more complex continuum damage mechanics constitutive equations. However, before performing an accurate FE analysis, the material properties for each material zone must be accurately determined.

In this presentation, laboratory tests required for generating the material constants in creep and continuum damage constitutive equations are briefly described. Strategies for modelling weld repairs are presented. Typical results of creep life prediction of welded structures operating at high temperatures and under creep-fatigue conditions are presented. The potential uses and limitations of the FE modelling of the creep of weld and weld repairs are discussed.