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EDITORIAL

Special issue of materials at high temperatures containing papers from the HIDA-7 conference

The HIDA-7 conference concerned with Life/Crack Assessment and Failures in Industrial Structures, in particular those operating at high temperatures, was held at Portsmouth University between 15 and 17 May 2017. This *Special Issue of Materials at High Temperature* contains papers accompanying some of the presentations at this conference.

HIDA was originally the acronym for an EU Commission and Industry supported research project, led by ETD Consulting, which aimed to develop a unified European High Temperature Defect Assessment procedure. The Brite-Euram HIDA project involved 11 organisations from 7 countries, with the effectiveness of the procedure developed being demonstrated using material models based on data generated and/or gathered for a number of CrMo(V), 9CrMoVNb and 17Cr12NiMo engineering steels. The original HIDA conference held at CEA (Saclay) in 1998 focused on the themes covered by the Brite-Euram project, and in particular topics concerned with crack growth and accurate assessment of the behaviour of high temperature plant components containing defects and operating under steady and/or cyclic loading conditions. The scope of more recent editions of the conference has extended to the consideration of aspects relating to life assessment and condition monitoring, and the characteristics and performance-in-service of newer advanced steels.

In the following, the 22 papers included in MHT's HIDA-7 Special Issue are reviewed under the headings: (i) Deformation and crack growth modelling, (ii) Life assessment and condition monitoring, and (iii) Advanced martensitic 9/10%Cr steels, although their content often concerns the consideration of more than one of these themes.

Deformation and crack growth modelling

There continue to be improvements in deformation and crack growth modelling, in particular for high temperature applications, and some of these are represented by the papers selected here for publication in this special issue.

Pohja et al. examine the influence of prior creep on fatigue and prior fatigue on the creep properties for P91 steel. It is claimed that a simple so-called Φ-model is more effective and robust for predicting the creep-fatigue life of P91 steel than the methods described in the design code RCC-MRx. In creep-fatigue assessments involving more traditional methodologies, data generation to provide the basis for visco-plastic cyclic-plasticity models can be expensive, and Thiele et al. present an approach to address this problem, in this case for a GJS X SiMo 4.1 iron.

The focus of the Xu paper is on creep modelling, and the use of a modified Sinh law to determine minimum creep rate, and boundary cavity area fraction to provide the basis for a rupture criterion.

Typically, lifetime assessment procedures for high temperature components incorporate conservatism to account for various uncertainties, and are thereby deterministic. Zentuti et al. outline the initial stages of developing a probabilistic methodology for assessments concerning creep and creep-fatigue.

Shankar & Mahato describe the use of finite element analysis to model vibration and control the structural integrity of delaminated and/or damaged composite plate structures.

Three papers are concerned with crack growth. Krämer et al. present the details of a creep-fatigue-oxidation interaction model for the determination of thermo-mechanical fatigue crack growth rates from isothermal test results, with particular application to nickel base superalloys. In contrast, Holdsworth & Chen consider the implications of oxidation and creep cracking on high frequency, high temperature, high-R (high K_{mean}) fatigue crack growth thresholds for 1CrMoV, 9CrMoCo and 18Cr8Mo steels.

Extended cohesive damage modelling (ECDM) is a robust computational approach for predicting multi-crack propagation in engineering materials and structures. The Li & Chen paper demonstrates the advantages of ECDM relative to XFEM, the currently preferred FEM based solution for simulating crack development.

Life assessment and condition monitoring

Yoshioka reviews the current status of Japanese thermal power plants, the materials used, and the technologies currently employed for their life and condition assessment, in particular with respect to steam and gas turbines. The Yoshioka paper is complemented by that of Fujiyama which is rather concerned with the application of: (i) a total life-cycle management methodology, (ii) statistical damage analyses and (iii) risk-based decision-making, to critical components of steam and gas turbines. Alternatively, the condition of steam condensers is considered by Moore, in a paper which examines candidate damage mechanisms in these power plant structures, and the means of avoidance.

In addition to the more general review papers concerning life assessment and inspection management, there are a number which focus on creep. One technique for assessing the creep deformation condition of service exposed material is impression-creep testing. Cacciapuoti et al. present the results of recent developments and consequent comparisons with new uniaxial specimen data for P91, P92 and ½CrMoV steels. While new miniature specimen creep testing techniques such as small-punch and impression-creep continue to evolve, there are recognised advantages in employing small tensile specimens for remaining life creep condition assessment when material availability permits. Miniature tensile specimen creep testing is employed by Erten et al. to characterise the creep rupture properties of an ex-service P91 weldment.

Yokobori et al. use a parameter referred to as QL^* to predict remnant creep fracture life. While QL^* is analogous to the Monkman-Grant constant, it is determined from the results of creep crack growth tests, and the use of miniature specimens is impractical. This difficulty has been overcome for the remaining life evaluation of Ni-base alloys by the determination of a relationship between QL^* and micro-grinding resistance.

The Shibli paper concerned with aberrant P91 (and introduced in the next section) also considers a number of new and novel techniques for condition monitoring during service of power plant components manufactured from advanced martensitic 9/10%Cr steels. His review included reference to the electromagnetic inspection techniques covered in greater detail in the Wilson et al. paper. Traditionally, electrical potential drop techniques have been used to monitor crack development, primarily in laboratory specimens but also in operating components. The Wojcik et al. paper explores the feasibility of using such techniques for the early detection of creep cavitation damage in particular in advanced martensitic 9/10%Cr steels.

Advanced martensitic 9/10%Cr steels

As mentioned above, Shibli highlights the fact that there can be circumstances when the microstructural condition of P91 is not the expected 100% tempered martensite, but may, for example, contain significant proportions of under or over tempered ferrite (i.e. referred to as aberrant P91) as a consequence of poor quality control during manufacture and/or fabrication. In these cases, the creep properties are unlikely to be fit-for-purpose and it is important to have advance warning of consequential adverse damage conditions. The Shibli paper also considers the inspection possibilities for monitoring in such circumstances, as do the papers of Wilson et al. and Wojcik et al.

Although there are now significant quantities of long duration creep rupture properties for Grade 91 parent steels, the available long term data for weldments is not so common. In addition to addressing this problem Tabuchi et al., highlight the fact that weld metal cracking can be as life limiting as Type-IV cracking after long times at 600 and 650°C. Predicting the remaining life of P91 weldments using an EBSD based crystal misorientation diagram is one of the main topics of the Hasegawa et al. paper. The creep deformation and rupture behaviour of a service exposed P91 welded joint is considered by Erten et al. Weldments involving other advanced martensitic 9/10%Cr steels are also increasingly receiving attention, as reflected by the detailed microstructural investigation of long term creep tested joints involving the COST F and FB2 alloys reported by Kasl & Jandova.

An important consideration in the structural integrity assessment of weldments is the residual stress state associated with weldments. The Venkata et al. paper considers this aspect for a dissimilar metal welded joint between P91 and TP316LN.

While P92 exhibits excellent creep properties, the applicability of this steel for high temperature pipework can be limited by its oxidation resistance. Hoey et al. demonstrate the feasibility and advantages of a new Co–Cr–C coating developed to protect the surface of this alloy at high application temperatures.

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