TECHNIQUES FOR MULTIAXIAL CREEP TESTING

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Mechanical Testing
Committee

Based on the edited proceedings of a symposium held at Central Electricity Research Laboratories, Leatherhead, UK, 25–26 September 1985.

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TECHNIQUES FOR MULTIAXIAL CREEP TESTING

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Introduction

The design and assessment of modern high temperature plant demands an understanding of the creep and rupture behaviour of materials under multiaxial stress states. Examples include thread roots in steam turbine casing bolts, branch connections in nuclear pressure vessels and blade root fixings in gas or steam turbine rotors. At one extreme the simple notch weakening/notch strengthening characterization of the material by circumferentially vee-notched uniaxial rupture tests, as specified in many national standards, may be sufficient. These were originally intended to model thread roots and their conservatism is such that they frequently are considered adequate for design purposes. At the other extreme full size or model component tests may be employed to determine the safety margins built into design codes. This latter approach is most commonly used for internally pressurized components, particularly where welds are involved. However, such tests are extremely expensive and the use of modern stress analysis techniques combined with a detailed knowledge of multiaxial properties offers a more economic alternative.

Design codes, by their nature, must ensure conservatism and are based on a material's minimum specified properties. In the case of high temperature components the extension of life beyond the nominal design figure, say from 100 000 to 200 000 h, offers very significant economic benefits. However, this may require a more detailed understanding of the multiaxial behaviour of a specific material than was available at the design stage.

Much effort has been devoted in recent years to quantifying the state of stress in multiaxial specimen geometries and to studying the deformation and rupture mechanisms and their dependence upon stress state. However, comparatively little attention has been paid to the practical difficulties associated with multiaxial testing. This may be contrasted with the situation which exists for uniaxial testing which is covered by national standards, largely because of the historical dependence of design procedures on reliable uniaxial data. In the future, increasing importance will be attached to multiaxial data and it is essential that testing techniques are soundly based in theory and are adequately controlled. It is also important to develop simplified techniques which may be used to generate the required volume of data economically. It is therefore an appropriate time to review the state of the multiaxial testing art both from a theoretical and practical standpoint.

For this reason the UK High Temperature Mechanical Testing Committee (UKHTMTC), whose secretariat is at the National Physical Laboratory (NPL), organized a symposium on *Techniques for Multiaxial Creep Testing* in September 1985. The meeting was held at the Central Electricity Research Laboratories (CERL) under the auspices of the Central Electricity Generating Board and ERA Technology Ltd. The primary aim of the UKHTMTC is to promote discussion, development and, where appropriate, standardization of testing techniques. This meeting was the third in a series devoted to techniques in pursuance of that aim. The first was held at NPL in 1981 and the proceedings were published as *Measurement of High Temperature Mechanical Properties of Materials* edited by M. S. Loveday, M. F. Day and B. F. Dyson (HMSO, London, 1982). The second was held at Preston in 1983 under the auspices of Springfields Nuclear Power Development Laboratories, the proceedings being published as *Techniques for High Temperature Fatigue Testing* edited by G. Sumner and V. B. Livesey (Elsevier Applied Science Publishers, London, 1985). The present volume comprises the edited proceedings of the 1985 meeting. The majority of papers were invited although a number of shorter contributed papers which highlight specific aspects are also included. It is hoped that the book will prove a valuable reference work for all concerned with the design and execution of multiaxial creep tests.

The introductory chapter outlines the theory of deformation and rupture under multiaxial conditions and gives examples of component studies for which an understanding of multiaxial behaviour is necessary. Following this the book is divided into three sections as at the conference. The first deals with biaxial techniques which are the most readily interpretable but which generally require purpose-built testing machines. The most common technique is the tension/torsion of thin-walled tubes which permits the application of stresses ranging from pure shear to pure tension. Accurate extensometry poses a particular problem in these tests and detailed descriptions of techniques developed to overcome this are given. A simplified double shear test which may be performed using standard creep machines is described in Chapter 2 and the ultimate biaxial test, the cruciform test, is the subject of Chapter 7.

The second section is concerned with triaxial techniques and Chapter 9 gives a comprehensive overview of the theory behind the most common of these, the circumferentially notched bar test, with the next two chapters covering the practical aspects. Triaxiality may also be induced by the superimposition of a hydrostatic stress upon a tensile test and Chapter 13 describes how this may be achieved. Finally, one of the most common causes of triaxiality is the mismatch of creep strength between weld metal and parent material in weldments and this is dealt with in Chapter 12. This area is of growing importance since the great majority of creep failures of thick section high temperature components occur at weldments where stress triaxiality leading to low ductility frequently is identified as the primary cause.

The last section covers the testing of pressurized tubes and components, these being the most realistic tests possible for most pressure vessels. They may be used to determine multiaxial stress rupture criteria but also permit the measurement of representative stresses for deformation and rupture for direct application to service situations. Chapter 14 summarizes the stress state theory and the subsequent chapters describe how theory is turned into practice. The final chapter culminates in a description of the ultimate multiaxial test, the full sized pressure vessel.

It remains to thank all those who contributed to the preparation of this book and the many people who assisted in the organization of the 1985 symposium. Particular thanks are due to the Organizing Committee, who also constituted the majority of the Editorial Panel, for many hours of their time. The support and assistance of colleagues at CERL and ERA, without whom the symposium would not have taken place, is also gratefully acknowledged. However, at the end of the day the success of a conference and its subsequent publication depends on the authors and it is to these that we extend our especial gratitude.

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