International Journal of Pressure Vessels and Piping 88 (2011) 158–165

Contents lists available at ScienceDirect

International Journal of Pressure Vessels and Piping

journal homepage: www.elsevier.com/locate/ijpvp

The extrapolation of creep rupture data by PD6605 – An independent case study

J. Bolton*

65 Fisher Avenue, Rugby, Warks CV22 5HW, United Kingdom

ARTICLE INFO

Article history:
Received 25 January 2010
Received in revised form
6 February 2011
Accepted 17 March 2011

Keywords:
Creep rupture
Extrapolation
Statistical modelling

ABSTRACT

The worked example presented in BSI document PD6605-1:1998, to illustrate the selection, validation and extrapolation of a creep rupture model using statistical analysis, was independently examined. Alternative rupture models were formulated and analysed by the same statistical methods, and were shown to represent the test data more accurately than the original model. Median rupture lives extrapolated from the original and alternative models were found to diverge widely under some conditions of practical interest.

The tests prescribed in PD6605 and employed to validate the original model were applied to the better of the alternative models. But the tests were unable to discriminate between the two, demonstrating that these tests fail to ensure reliability in extrapolation. The difficulties of determining when a model is sufficiently reliable for use in extrapolation are discussed and some proposals are made.

1. Introduction

The prohibitive cost of long-term rupture testing for creep-resistant steels and other engineering alloys has led to the development of numerous procedures whereby data for limited test times are extrapolated to commercially useful lifetimes. Such procedures first represent the available data by a graphical or mathematical model that reflects the observed dependence of mean rupture life upon stress and temperature, then extrapolate that model assuming that it is a reliable predictor of behaviour over somewhat longer times. There is no guarantee that this will be so, since, for example, changes in microstructure might precipitate an unanticipated change in behaviour. However, the prediction is presumed to be reliable provided that there is no evidence to the contrary, i.e. provided that the following conditions are met:

(i) The model accurately follows the variation of rupture time with stress and temperature displayed by the test results for typical casts,
(ii) The model is well behaved over the extrapolated interval, exhibiting no changes in curvature that appear to originate only in the mathematical formulation of the model,
(iii) There is no separate body of data for a similar alloy that contradicts the extrapolated trend of the model, such as the analyst should also take into account.

This paper discusses the assessment of rupture models for a single dataset, without subsequent adjustments based on data for any similar alloy, and incorporating no deliberate conservatism. In this context, judgement of the reliability of extrapolation depends only upon the model's accuracy in representing the data and its orderly behaviour over the extrapolated interval.

One such extrapolation method, which has been widely promoted in Europe and the United States, is presented in British Standard document PD6605-1:1998 [1]. This document presents a statistical procedure for finding an optimised mathematical model of the dependence of median rupture life on stress and temperature. It includes recommended tests for verifying the reliability of that model, so that a model based on data terminating at, for example, 100,000 h may be extrapolated to two or three times that duration with some confidence. The statistical method at the core of this procedure is described in Ref. [2]. It consists of iterating the numerical coefficients of each of a series of candidate equations, first to optimise their coefficients and then to determine which has the greatest likelihood of being an accurate model. A library of candidate equations for established rupture models is recommended in Ref. [1], and the user may introduce other equations. The statistical method employed to calculate numerical values of Likelihood or Deviance for each model is recapitulated here in Appendix 1. A recent and generally favourable review of the PD6605 procedure has been published as Ref. [3].

Appendix C of PD6605 presents a worked example to illustrate the recommended analysis and validity tests. A preferred model, from the standard library, is established and validated, and extrapolated median rupture properties are then determined. It is

* Tel.: +44 (0) 1788 565366.
E-mail address: john.bolton@uwclub.net.

0308-0161/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijpvp.2011.03.001