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Best Practice Guideline for Statistical Analyses of Fatigue Results

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Preface

This guide is the joining together of the following IIW documents:

- Best practice guide on statistical analysis of fatigue data (doc-XIII-2138-06):

C. R. A. Schneider	TWI (Cambridge—UK)
S. J. Maddox	TWI (Cambridge—UK)

- Guidance for the application of the best practice guide on statistical analysis of fatigue—working sheets (doc XIII-WG1-188-17):

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Recommendations for analysing fatigue data are available, but they do not deal with all the statistical treatments that may be required to utilise fatigue test results, and none of them offers specific guidelines for analysing fatigue data obtained from tests on welded specimens.

The subject of the present guide is to provide to engineers a comprehensive guidance for the use of sound statistical methods and for the evaluation of fatigue data of welded components and structures obtained under constant amplitude loading and used to produce SN curves.

For an easy use, working sheets are provided to assist in the proper statistical assessment of experimental fatigue data concerning practical problems giving the procedure and a numerical application as illustration.

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Chapter 1
Best Practice on Statistical Analysis of Fatigue Data

1.1 Introduction

Fatigue testing is the main basis of the relationship between the fatigue resistance of a given material, component or structural detail and cyclic loading. The results of such fatigue endurance tests are plotted on graphs relating applied loading (force, stress, strain, etc.) and the number of cycles to failure. Since test specimens and testing conditions are never identical, the resulting data are invariably scattered. Consequently, some judgement is required when using them to establish the required relationship. Statistical methods are available to assist in this analysis of fatigue test data, and indeed some recommendations on their use for analysing fatigue data are available [1, 2]. However, they do not deal with all the statistical analyses that may be required to utilise fatigue test results and none of them offers specific guidelines for analysing fatigue data obtained from tests on welded specimens. With the increasing use of fatigue testing to supplement design rules, an approach that is now encouraged in some Standards [3, 4, 25], there is a need for comprehensive guidance on the statistical analysis of fatigue test results.

This is the subject of the present best practice guide. At this stage, the focus is on fatigue endurance test results obtained under constant amplitude loading, as used to produce S–N curves. Thus, the loading is expressed as a stress range, S, and the fatigue resistance is expressed as the number of cycles, N, that can be endured by the test specimen. In general, however, the same methods can be applied to fatigue endurance test results expressed using any measure of the loading (e.g. force, strain) and results obtained under variable amplitude loading. They can also be used to analyse fatigue crack propagation data, where the loading is expressed as the stress intensity factor range, ΔK, and the fatigue resistance is expressed as the rate of crack propagation $\mathrm{d}a/\mathrm{d}N$. Since the analyses are concerned purely with the experimental data, they are independent of the material tested.

G. Parmentier et al., *Best Practice Guideline for Statistical Analyses of Fatigue Results*, IIW Collection, https://doi.org/10.1007/978-3-031-23570-2_1

1.2 Assumptions

1.2.1 Form of S–N Curve

(a) There is an underlying linear relationship between log *S* and log *N* of the form:

$$\log N = \log A - m \log S \tag{1.1}$$

where *m* is the slope and log *A* is the intercept. This can be rewritten in a form that is commonly used to describe *S–N* curves in design rules:

$$S^{m} N = A \tag{1.2}$$

Note that, in practice, this assumption will only hold true between certain limits on *S*, as illustrated in Fig. 1.1. The lower limit on *S* is determined by the fatigue endurance limit (or just "fatigue limit"), the stress range below which fatigue failure will not occur. In practice this is usually chosen on the basis of the endurance that can be achieved without any evidence of fatigue cracking, typically between $N = 2 \times 10^6$ and 10^7 cycles. The upper limit on *S* is dependent on the static strength of the test specimen but is commonly taken to be the maximum allowable static design stress [5].

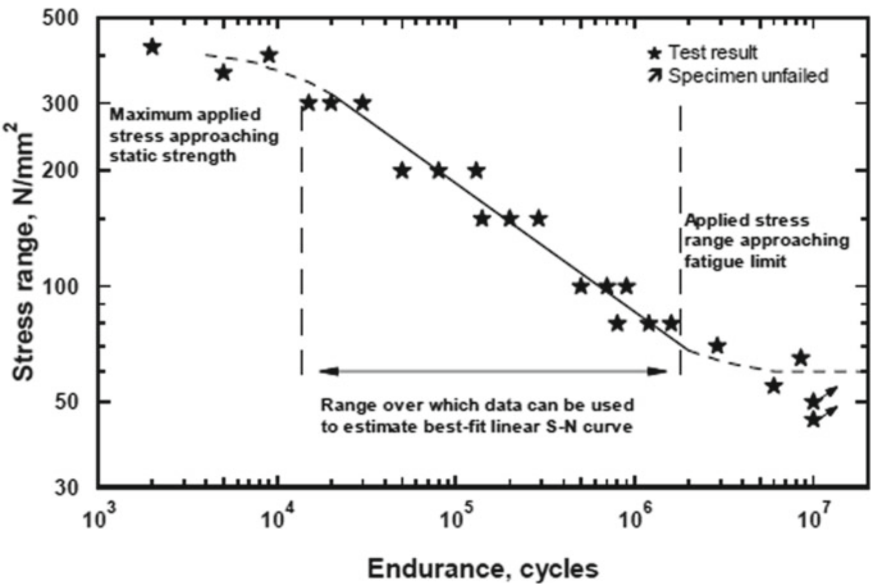

Fig. 1.1 Typical fatigue endurance test data illustrating deviations from linear *S–N* curve