

METHODS OF FATIGUE TESTING

Part 1. General Principles

B.S. 3518 : Part 1 : 1962

BRITISH STANDARDS INSTITUTION

Incorporated by Royal Charter

2 PARK STREET, LONDON W1A 2BS

Telex: 266933

Telephone: 01-629 9000

UDC 620.178.3

Documents
Document Sharing Hub

THIS BRITISH STANDARD, having been approved by the Mechanical Engineering Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 3rd July, 1962.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 4000, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. references relate to the work on this standard:
Committee references MEE/37 and MEE/37/12
Draft for comment AB(MEE) 913



Documents

Document Sharing Hub

CONTENTS

	Page
Co-operating organizations	4
Foreword	5

GENERAL PRINCIPLES

1. Scope	6
2. Common terms	6
3. Terms, definitions and symbols	7
4. Test conditions and criteria of failure	10
5. Special fatigue tests	12
6. Presentation of results	13
7. Application of statistical methods	14

FIGURES

1. Fatigue test cycle	16
2. The stress cycle with algebraic notation	17
3. Types of cyclic stress	17
4. S/N curve (linear stress scale)	18
5. S/N curves (logarithmic stress scale)	19
6. S/N curves corresponding to particular mean stresses (linear stress scale)	20
7. S/N curves corresponding to particular stress ratios (logarithmic stress scale)	21
8. Axial load fatigue test results (Haigh diagram)	22
9. Haigh diagram	23
10. Maximum and minimum S_{max} and S_{min} against mean stress S_m (Smith diagram)	24
11. Maximum and minimum S_{max} and S_{min} against mean stress S_m (Smith diagram)	25
12. Maximum stress S_{max} against minimum stress S_{min} (Rös diagram)	26
13. Maximum stress S_{max} against minimum stress S_{min} (Rös diagram)	27

CO-OPERATING ORGANIZATIONS

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- Admiralty
- Air Ministry
- Associated Offices' Technical Committee
- Association of Consulting Engineers (Incorporated)
- Association of Mining Electrical and Mechanical Engineers
- British Chemical Plant Manufacturers' Association
- British Compressed Air Society
- British Electrical and Allied Manufacturers' Association
- British Engineers' Association
- British Gear Manufacturers' Association
- British Internal Combustion Engine Manufacturers' Association
- *British Iron and Steel Federation
- *British Railways, The British Transport Commission
- Crown Agents for Oversea Governments and Administrations
- *D.S.I.R.—National Engineering Laboratory
- Electricity Council, The Generating Board and the Area Boards in England and Wales
- Engineering Equipment Users' Association
- Gas Council
- High Commission of India
- Institute of Marine Engineers
- Institute of Petroleum
- Institution of Civil Engineers
- Institution of Gas Engineers
- Institution of Heating and Ventilating Engineers
- Institution of Mechanical Engineers
- Institution of Mechanical Engineers (Automobile Division)
- *Institution of Production Engineers
- Locomotive and Allied Manufacturers' Association of Great Britain
- Machine Tool Trades Association
- Ministry of Labour (Factory Inspectorate)
- Ministry of Power
- Ministry of Transport
- Ministry of Works
- National Coal Board
- *National Physical Laboratory (D.S.I.R.)
- Radio Industry Council
- *War Office

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard:

- Aluminium Development Association
- Aluminium Industry Council
- British Cast Iron Research Association
- British Non-ferrous Metals Research Association
- British Welding Research Association
- Copper Development Association
- D.S.I.R.—Building Research Station
- D.S.I.R.—Forest Products Laboratory
- Institute of Welding
- Institution of Engineering Inspection
- Ministry of Aviation
- Royal Aeronautical Society
- Society of British Aircraft Constructors
- Spring Manufacturers' Research Association
- Individual manufacturers of testing machines



Documents

Document Sharing Hub

BRITISH STANDARD SPECIFICATION FOR METHODS OF FATIGUE TESTING

Part 1. General Principles

FOREWORD

In 1959 Technical Committee TC 17 (Steel) of the International Organization for Standardization (ISO) began work on the preparation of a Recommendation for fatigue testing. The ISO Technical Committee was well aware that any national standards based on this Recommendation would be utilized more by research laboratories than by test houses concerned with acceptance tests of material products. It was felt, nonetheless, that the document could serve a useful purpose in promoting international agreement particularly as to terms and the meanings assigned to them, and to methods of presenting the results of fatigue tests. Accordingly, the Recommendation initially drafted by the United Kingdom Secretariat, has been discussed and amended by Technical Committee TC 17, and will, in due course, be published by ISO.

Though membership of ISO does not imply that a member country should, as a matter of course, issue its own national standard to correspond with every ISO Recommendation, the drafting sub-committee which prepared the first draft for ISO considered that a British Standard on fatigue testing could be of practical value. Part 1 of the standard has, therefore, been prepared, in form and content following closely those of the ISO Draft Recommendation, to outline the general principles of fatigue testing, and it is proposed subsequently to issue further parts standardizing procedures for particular types of test, or special aspects of fatigue testing. Their purpose will be to provide a framework within which some measure of uniformity of procedure can be achieved. It should not be inferred that one method of test is superior to another.

Unlike the tensile test, for which it is possible to standardize test pieces almost without reference to the machines in which they are to be broken, the fatigue test is one in which the form of the test piece and the design of the machine are intimately related. There is considerable variety to be found even among the small test pieces used to compare materials in terms of their 'basic' fatigue properties, and in the machines employed to test them. In the fatigue testing field viewed as a whole, the variety of machines and test rigs used is immense, and that of test pieces practically unlimited.

The publication of these standards is not intended to encourage the introduction of fatigue tests as acceptance tests for materials whose suitability for constructional purposes can be checked by simpler means, but rather to be of assistance in cases where a particular application calls for this specialized form of testing.

GENERAL PRINCIPLES

SCOPE

1. This British Standard makes recommendations for general principles to be followed in carrying out fatigue tests, i.e. tests under conditions in which a pattern of loading is repeated a large number of times, for nomenclature and symbols, and for the presentation of results in such a way that the maximum amount of useful information may be conveyed. For the benefit of users of the standard who are unfamiliar with the present day broad field of fatigue testing, some terms commonly encountered are briefly explained in the next section.

For reasons of simplicity, throughout the later sections of the standard discussion of stresses is generally worded as though they were purely tension (taken as positive) or compression (taken as negative), though all references to stresses complying with these simple cases are equally applicable to other stress systems.

COMMON TERMS

2. *Direct stress.* The material is repeatedly loaded along its major axis.

EXAMPLE: the loading on a piston rod.

Plane bending. The material is repeatedly bent about a particular neutral plane.

EXAMPLE: the loading applied to leaf springs.

Rotating bending. The material is bent with the neutral plane continually rotating with respect to the test piece.

EXAMPLE: the loading on the rotating axle of a railway wagon.

Torsion. The material is repeatedly twisted about a fixed axis.

EXAMPLE: a vehicle suspension torsion bar.

Combined stresses. The material is stressed under a combination of two (or more) of the above types of loading.

EXAMPLE: the loading on a crankshaft journal (bending and torsion).

Stress. In general the stress will be a nominal stress calculated by reference to the net section under consideration. It will usually be calculated by the use of conventional elastic formulae but may sometimes be calculated from the measured strain.

It should be noted that in some instances tests may be conducted and the results expressed entirely in terms of strain; in particular, where strains beyond the elastic limit are employed it is undesirable to calculate stresses from them.

The applied stress cycle. It will be seen from Fig. 1, illustrating a sinusoidal cycle, that the smallest section of the stress-time function which is repeated periodically is the stress-cycle and that any stress varying periodically over a given range can be regarded as comprising a component alternating between

two values opposite in sign but equal in magnitude (the stress amplitude) with a static stress (the mean stress) superimposed. The recommended notation is algebraic as in Fig. 2.

The stress cycle may take any of the forms shown in Fig. 3.

TERMS, DEFINITIONS AND SYMBOLS

3. The following table lists quantities which are often represented by symbols, together with their definitions, and recommendations as to the symbols which should be employed. Symbols adopted by ISO are given for information:

Term	Definition	Recommended symbol	ISO symbol
Maximum stress	The highest algebraic value of stress in the stress cycle; tensile stress is considered positive and compressive stress negative.	$S_{\max}$ $\sigma_{\max}$	$\sigma_{\max}$
Minimum stress	The lowest algebraic value of stress in the stress cycle; tensile stress is considered positive and compressive stress negative.	$S_{\min}$ $\sigma_{\min}$	$\sigma_{\min}$
Mean stress	The static component of the stress. It is one-half of the algebraic sum of the maximum and minimum stresses.	S_m σ_m	σ_m
Stress amplitude	The variable component of stress. It is one-half of the algebraic difference between the maximum stress and the minimum stress.	S_a σ_a	σ_a
Range of stress	The algebraic difference between the upper stress and lower stress in the stress cycle.	$2S_a$ $2\sigma_a$	$2\sigma_a$
Number of stress cycles	The number of cycles applied at any stage during the test.	n	n

NOTE. For shear stress, the symbol q or τ respectively should be used instead of S or σ .

Term	Definition	Recommended symbol	ISO symbol
Frequency of stress cycles	The number of applied cycles per unit time (c/min or c/s).	—	—
Theoretical stress concentration factor	Theoretical elastic or geometric stress concentration factor based on net area.	K_t	K_t
Stress ratio	The algebraic ratio of the minimum stress and the maximum stress in one cycle: $\frac{S_{min.}}{S_{max.}}$ or $\frac{\sigma_{min.}}{\sigma_{max.}}$	R R_s	R_s
Fatigue life or endurance	The number of stress cycles to failure, generally stated as decimal fractions or multiples of 10^6 .	N	N
Fatigue limit	The value, which may be statistically determined, of the stress condition below which a material may endure an infinite number of stress cycles. If S_a is the stress amplitude at the fatigue limit, then $S_D = S_m \pm S_a$ for a particular value of the mean stress S_m . NOTE. Most materials and environments preclude the attainment of well defined fatigue limits.	S_D σ_D	σ_D
Fatigue strength at N cycles or fatigue strength for finite life (sometimes known as endurance limit)	The value of the stress condition under which the test specimen would have a life (which may be statistically determined) of N cycles. If S_a is the stress amplitude for N cycles, then $S_N = S_m \pm S_a$ for a particular value of mean stress S_m .	S_N σ_N	σ_N



Term	Definition	Recommended symbol	ISO symbol
Cycle ratio	The ratio of the applied stress cycles to cycles to failure.	n/N	n/N
Fatigue strength reduction factor (based on the net area)	The ratio of the stress amplitude at the fatigue limit for plain polished test pieces to that for test pieces with a stress concentration, * i.e. $K_f = \frac{S_a}{S'_a}$ The concept of a fatigue strength reduction factor was originally introduced in respect of fatigue tests made under zero mean stress, and it will be noted that the above definition takes no account of mean stress. In some fields of application it is convenient to undertake tests on test pieces both with and without a stress concentration using the same nominal value of mean stress. In others, it is considered important to acknowledge that both the mean stress and the alternating stress are locally intensified at the stress concentration. Each individual test is made using a fixed ratio of mean stress to stress amplitude.	K_f	K

*The term 'stress concentration' is here used in a general sense, to denote not only the effect of a mechanical notch, but also, for example, the influence of corrosion or an unmachined surface.