BS ISO 12110-1:2013

BSI Standards Publication

Metallic materials — Fatigue testing — Variable amplitude fatigue testing

Part 1: General principles, test method and reporting requirements

bsi.

...making excellence a habit.™

Document Sharing Hub

National foreword

This British Standard is the UK implementation of ISO 12110-1:2013.

The UK participation in its preparation was entrusted to Technical Committee ISE/101/6, Fatigue testing of metals and metal matrix composites.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2013. Published by BSI Standards Limited 2013

ISBN 978 0 580 69935 1

ICS 77.040.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2013.

Amendments issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS ISO 12110-1:2013

INTERNATIONAL STANDARD

ISO 12110-1

First edition
2013-07-01

Metallic materials — Fatigue testing — Variable amplitude fatigue testing —

Part 1: General principles, test method and reporting requirements

Matériaux métalliques — Essais de fatigue — Essais sous amplitude variable —

Partie 1: Principes généraux, méthode d'essai et exigences sur le rapport d'essai

Reference number
ISO 12110-1:2013(E)

Documents
Document Sharing Hub

© ISO 2013

Full document details: BS ISO 12110-1:2013

COPYRIGHT PROTECTED DOCUMENT

© ISO 2013

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 12110-1:2013

Contents

Page

Foreword ... **iv**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms and definitions ... **2**

4 Principle of test ... **4**
4.1 Control signal generation ... 4
4.2 Overview of test procedure ... 4

5 Original loading time history ... **5**
5.1 General ... 5
5.2 Data filtering ... 5

6 Loading time history description ... **6**
6.1 General ... 6
6.2 Time history sequences description ... 6
6.3 Cycle counting description ... 6

7 Programmed blocks ... **7**

8 Transition matrix and generation of control signal from the matrix ... **7**
8.1 Establishment of the matrix ... 7
8.2 Reconstruction of the loading signal ... 8
8.3 Control signal simplification ... 9

9 Conducting fatigue testing under variable amplitude conditions ... **9**

10 Test report for each individual specimen ... **10**
10.1 General ... 10
10.2 Original loading description ... 10
10.3 Testing conditions ... 10
10.4 Preliminary analysis of test data for each specimen and for a series of specimens ... 12

Annex A (informative) **Standard loading time histories** ... **18**

Annex B (informative) **Example of loading signal reconstruction by random draw in the transition matrix** ... **19**

Annex C (informative) **Preliminary analysis of test data on a single specimen** ... **21**

Bibliography ... **24**

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

ISO 12110 consists of the following parts, under the general title *Metallic materials — Fatigue testing — Variable amplitude fatigue testing*:

— *Part 1: General principles, test method and reporting requirements*

— *Part 2: Cycle counting and related data reduction methods*

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

INTERNATIONAL STANDARD ISO 12110-1:2013(E)

Metallic materials — Fatigue testing — Variable amplitude fatigue testing —

Part 1: General principles, test method and reporting requirements

1 Scope

This part of ISO 12110 establishes general principles for fatigue testing of laboratory specimens under a sequence of cycles the amplitude of which varies from cycle to cycle.

This sequence of cycles is called loading time history (see 3.7) and is usually derived from loading measurements performed on components or structures submitted to true service loadings.

Detailed description of service loads recording is relevant to each laboratory or industrial sector and is therefore outside the scope of this part of ISO 12110.

The aim of the two parts of ISO 12110 is to set requirements and give some guidance on how to perform a variable amplitude fatigue test in order to produce consistent results for comparison purposes taking into account the typical scatter of fatigue data. Achieving this should help designers to correlate models and experimental data obtained from various sources.

Since this part of ISO 12110 involves mainly loading time histories and control signal generation, one expects it might be applied to strain or fatigue crack growth rate controlled loading conditions as well as to force-controlled loading conditions. This is theoretically true but precautions may be taken when applying this part of ISO 12110 to loading modes other than force-controlled loading mode.

This part of ISO 12110 relates to variable amplitude loading under force control mode which corresponds to most of the variable amplitude fatigue tests performed worldwide at the date of publication of this part of ISO 12110.

This part of ISO 12110 applies to the single actuator loading mode which corresponds to uniaxial loading in many cases.

The variable amplitude loading time histories referred in this part of ISO 12110 are deterministic; that is why this part of ISO 12110 deals with variable amplitude loading instead of random loading.

The following issues are not within the scope of this part of ISO 12110 and therefore will not be addressed.

— constant amplitude tests with isolated overloads or underloads;

— tests on large components or structures;

— environmental effects like corrosion, creep linked to temperature/time interactions leading to frequency and waveform effects;

— multiaxial loading.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1099, *Metallic materials — Fatigue testing — Axial force-controlled method*

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

ISO 12106, *Metallic materials — Fatigue testing — Axial-strain-controlled method*

ISO 12107, *Metallic materials — Fatigue testing — Statistical planning and analysis of data*

ISO 12108, *Metallic materials — Fatigue testing — Fatigue crack growth method*

ISO 23788, *Metallic materials — Verification of the alignment of fatigue testing machines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1099, ISO 12106, ISO 12107, and ISO 12108 and the following apply.

3.1
cumulative frequency diagram
histogram showing the cumulative occurrence of each cycle since the beginning of the test

Note 1 to entry: The cumulative frequency diagram is also called cumulative spectrum or cumulative distribution.

3.2
cycle
smallest segment of the force-time, stress-time, or strain-time, or another signal that is applied to the specimen, which is repeated periodically under constant amplitude fatigue loading

Note 1 to entry: In variable amplitude loading, the definition of cycle varies with the counting method used.

3.3
cycle counting method
method to count the number of cycles of a loading time history of a given length

3.4
loading
generic term designating varying force, strain, or any other controlling variable applied to a specimen

Note 1 to entry: The present standard refers mostly to controlled force loading mode.

3.5
loading distribution
simple or cumulative distribution of load cycle ranges

Note 1 to entry: The loading distribution is the result of a statistical treatment of a record of true service loading or is a typical distribution specific to an industrial sector (e.g. automotive, aerospace). Loading distribution applies for load/stress control mode as well as strain control mode and other loading modes.

Note 2 to entry: The loading distribution is often called “loading spectrum”. Nevertheless, the word spectrum shall be avoided since it means a loading description in the frequency domain.

3.6
loading histogram
simple or cumulative histogram of load cycle ranges

Note 1 to entry: The loading histogram is the result of a statistical treatment of a record of true service loading or is a typical distribution specific to an industrial sector (e.g. automotive, aerospace). Loading histogram applies for load/stress control mode as well as strain control mode and other loading modes.

Note 2 to entry: The loading histogram is often called “loading spectrum”. Nevertheless, the word spectrum shall be avoided since it means a loading description in the frequency domain.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

3.7
loading time history
sequence of load cycles the amplitude of which varies from one cycle to the next

Note 1 to entry: The loading time history is a record of true service loading or is a typical sequence specific to an industrial sector (e.g. automotive, aerospace). Loading time history applies for load/stress control mode as well as strain control mode and other loading modes.

Note 2 to entry: In force-controlled loading mode, the term "force history" should have been used but this is not common within the variable amplitude fatigue community. "Loading time history" is always used whatever the controlling variable including force.

3.8
loading power spectrum
energy density spectrum
description of a random loading time history in the frequency domain

Note 1 to entry: The power spectrum is a Fourier integral of the time signal correlation function.

3.9
omission
eliminating of non-damaging cycles or cycles with amplitude less than the omission level

3.10
omission level
cutoff level for eliminating non-damaging cycles

3.11
peak
point at which the first derivative of the load-time history changes from a positive to a negative sign

Note 1 to entry: For a constant amplitude loading, the peak corresponds to the maximum loading. For variable amplitude loading, the peak corresponds to a local maximum load in the load-time history.

3.12
random draw
sequence of half cycles with different ranges and mean values

3.13
valley
part at which the first derivative of the load-time history changes from a negative to a positive sign

Note 1 to entry: The valley is a relative minimum or "trough".

Note 2 to entry: The valley is the point of minimum load in constant amplitude loading.

3.14
variable amplitude loading
loading mode in which all the peak or valley loads are not equal or both

Note 1 to entry: It is also called "irregular loading".

Note 2 to entry: The term "spectrum loading" is incorrectly employed instead of variable amplitude loading. It should be avoided since a spectrum is a loading description in the frequency domain, not a load versus time function.

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

4 Principle of test

4.1 Control signal generation

In most cases, the original loading time history cannot be directly applied to the specimen without any simplification since it is too difficult to derive any cycle number or cycles to failure from it and to control the fatigue testing machine effectively directly from it.

In addition, real loading time history records applied to the specimen whatever their number will never be representative of the true loading which can be only derived from a thorough statistical evaluation of the loading signal. Those statistical characteristics are determined from a very large number of true loading measurements.

Thus, the original loading time history needs to be simplified. This is usually done by signal analysis loading to two kinds of modelled loading control signals. These two kinds of modelled control signals are obtained by programmed blocks or signal reconstruction from random draw in a transition matrix.

Original loading time history without any simplification can be applied to the specimen if the testing machine and related electronics can do so.

In these cases, the analysis of the original signal is performed using a method called cycle counting.

The data obtained from cycle counting is then used to build a cumulative frequency diagram for block programming or a transition matrix for random draw.

NOTE 1 The main advantage of programmed blocks is that the control signal consists of a series of blocks of constant amplitude, which varies from one block to another. Hence, sophisticated digital control signal generation by computer is not needed.

NOTE 2 Whatever the complexity of the control signal reconstructed by random draw from a transition matrix, it remains much more representative of the real loading than programmed blocks derived from the same real loading. In addition, control signal generation through random draw has been made easier and easier over the last decades due to the spectacular improvement of digital electronics and computers.

Sometimes, filtering of signals is necessary for the following reasons.

a) The original signal obtained from direct measurement on components loaded in service is often polluted by electronic noise or other undesirable vibrations which are not caused by the fatigue process. Those disturbing vibrations have to be eliminated before applying the cycle counting procedure to the original signal.

b) An omission may be carried out to eliminate the non-damaging cycles (smallest cycles) from the control signal obtained from block programming or random draw to significantly reduce the test duration when results are needed quickly since those non-damaging cycles are generally the most numerous ones (see 8.3).

However, filtering shall be performed with great caution by choosing the most relevant filtering parameters. Inadequate filtering may lead to neglecting significantly damaging fatigue cycles.

Care shall be taken as well when considering mean stresses, residual stress effects, isolated very high amplitude overloads, etc.

NOTE 3 When the loading time history presents high isolated stress amplitudes, these high isolated stress amplitudes can actually increase fatigue life due to the beneficial residual stresses they cause.

4.2 Overview of test procedure

The variable amplitude fatigue test consists in loading the specimen using the control signal obtained from a cumulative frequency diagram (programmed blocks) or random draw.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013

The specimen's response is monitored through measurements given by load cell or force transducer or extensometry. These output data are used for closed loop control.

NOTE Variable amplitude fatigue testing usually uses servo-hydraulic test facilities, but the usage of other actuators is possible in the case of a closed loop controlled test.

When the specimen fails either by breaking in two parts or by reaching another failure criterion, the test results are reported. The test results may include the number of cycles or sequences to failure, crack propagation measurements, or any another specimen damage process data.

The test principle is summarized in the flow chart presented in Figure 1. Details about the main steps of the test are reported in the following sections of the present standard.

5 Original loading time history

5.1 General

The original component or structure loading time history comes from two sources.

a) The first source is direct measurement of in-service component or structure loading. To make these direct measurements, components and structures are instrumented with strain gauges or other sensing devices and digital data acquisition systems perform the recording and storage of the measurements.

   NOTE Car wheels, suspension systems, railway bogies, turbine blades, aircraft wing spars are typical components which experience fatigue loads.

b) The second source is standardized loading time history typical of an industrial sector. Its significance is generally acknowledged by most of those involved in the relevant industrial sector.

The original loading time history often consists in repeating a loading sequence of a given length (time or number of cycles) which remains the same. Only very slight changes may be observed from a sequence to the next.

In the case of original loading time history determined from direct measurement of in-service component loading, filtering may be necessary to eliminate electronic or mechanical noise. However, filtering parameters shall be set with caution to avoid elimination of significant damaging fatigue cycles.

The mean stress modulated filtering method may be used (see 8.3).

5.2 Data filtering

5.2.1 General

Efficient data filtering may reduce drastically the amount of data to be used to produce a variable amplitude fatigue control signal.

However, filtering generally involves a critical or threshold value of the load or load amplitude which has to be set.

The critical or threshold value shall be chosen taking into account the available knowledge and experience of the fatigue process under study and especially avoiding neglecting true damaging cycles which play a major role in the fatigue damaging process of the specimen or component involved.

5.2.2 Noise filtering

It consists in neglecting generally high frequency and low amplitude peaks superimposed to the fatigue loading signal which do not contribute to the fatigue process, e.g. electronic noise produced by the

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 12110-1:2013