BS 7935-1:2004

Constant amplitude dynamic force calibration —

Part 1: Calibration and verification of non-resonant uniaxial dynamic testing systems — Method

ICS 29.040

British Standards

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Foreword

This part of BS 7935 has been prepared under the authority of Technical Committee ISE/NFE/4. It supersedes Draft for Development DD 2:1971, which is withdrawn.

It specifies a method for determining the relationship between the true force range applied to a test-piece subject to constant amplitude uniaxial sinusoidal loading and the force range indicated by the testing system.

BS 7935-2 describes a method for performing the calibration of the calibration device instrumentation used in the method given in this standard.

This British Standard describes methods of constant amplitude dynamic force calibration of non-resonant uniaxial testing systems only, and should not be used or quoted as a specification for resonant test machines. References to this standard should indicate that the methods of dynamic force calibration used are in accordance with BS 7935-1.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 9 and a back cover.

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Introduction

In a dynamic test, the true force experienced by the test-piece might differ significantly from the force indicated by the testing system. This error results from inertia force acting on the loadcell and any errors in the electronics of the dynamic force indicating system. Inertia forces equate to the grip mass (interposed between the loadcell and test-piece) multiplied by its local acceleration. Inertia forces depend on:

a) the amplitude of motion;

b) the frequency;

c) the grip mass;

d) the compliance of the test-piece;

e) the configuration of the testing system e.g. frame compliance and type of mounting.

For the purpose of this standard dynamic verification is carried out using either Method A or Method B as described below.

Method A (Replica Test-Piece Method): This method is used for calibrating a dynamic testing system with a single test-piece configuration, correcting for errors of up to 5 % in the machine using a conversion function generated by this method. Before commencing a new series of dynamic tests, the conversion function can be determined relating indicated dynamic force range to true force range for a gauged replica test-piece. This can be applied either as a correction to the results or to modify the force applied by the testing system, to reduce the error to less than 1 %.

Method B (Compliance Envelope Method): This method is used for calibrating a dynamic testing system for use with varying test piece configuration. An operating envelope of test-piece compliance versus frequency can be established for the testing system, within which force errors are maintained to less than 1 %. This applies only to situations where the load train has the same mass as, or less mass than, the load train used for the dynamic calibration.

1 Scope

This part of BS 7935 describes two methods (see Introduction) for determining the relationship between the true dynamic force range applied to a test-piece in a uniaxial sinusoidal constant-amplitude test and the force range indicated by the testing system.

These methods are applicable to servo controlled testing systems operating outside system resonant frequencies and are relevant to testing systems where the inertia force is unknown or where it is expected to exceed 1.0 % of the true force range.

NOTE Annex A gives guidance on when the system should be re-calibrated by methods described in this standard.

2 Normative references

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

BS 7935-2, *Constant amplitude dynamic force calibration — Part 2: Calibration of the calibration device instrumentation to be used for the dynamic calibration of non-resonant uniaxial dynamic testing systems — Method.*

BS EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force measuring system.*

3 Terms and definitions

For the purposes of this part of BS 7935, the terms and definitions in BS 7935-2 and the following apply.

3.1
calibration device
replica test-piece or proving device

3.2
conversion function
relationship between the dynamic force range determined by a replica test-piece and the dynamic force range, indicated by a given testing system, over a range of frequencies

3.3
correction factor
ratio between the dynamic force range determined by a replica test-piece and the dynamic force range indicated by a given testing system, at a given frequency

3.4
dynamic testing system
combination of actuator, reaction frame, load train and instrumentation used to perform cyclic force testing

3.5
force range
difference between the maximum and minimum peak values of force under cyclic conditions

3.6
load train
components between the actuator and the reaction frame of the dynamic testing system

NOTE A load train includes, for example loadcell, adaptors, grips and fixtures.

4 Principle

Errors in dynamic force indication are determined by comparison of the peaks indicated by the dynamic testing system with those measured by the calibration device. This calibration device has previously undergone static calibration (see **6.2.1**) to the testing system indicator.

For Method A, the calibration is applicable over a range of frequencies validated for that type of test-piece only. A frequency dependant correction factor is applicable.

For Method B, the calibration is applicable over the range of frequencies validated for test-pieces whose compliance lies between those of the two proving devices. No correction factor is applicable.

5 Apparatus

5.1 *Calibration device instrumentation*, is calibrated in accordance with BS 7935-2.

5.2 *Calibration device*, is a replica test-piece, for Method A or proving devices for Method B.

5.3 *Proving device*, is a dynamic force measurement instrument comprising force sensor with known compliance.

5.4 *Replica test-piece*, is a strain gauged test-piece, with the strain gauge impedance matched to the calibration device instrumentation, having nominally identical geometry and Young's Modulus to the test-pieces.

6 General requirements

6.1 Temperature

The temperature at which the calibration of the non-resonant uniaxial dynamic testing system is performed shall be recorded.

NOTE 1 It is recommended that the calibration is performed at a constant ambient temperature.

NOTE 2 In the case of a strain gauged test-piece used as a calibration device, care should be taken to shield it from drafts and direct sunlight.

6.2 Dynamic testing system

6.2.1 *Static calibration*

The dynamic testing system shall have a current certificate of calibration to BS EN ISO 7500-1, class 1 or better for the relevant load condition.

6.2.2 *Calibration frequencies*

The dynamic testing system shall be calibrated over a range of frequencies, with the exception of any frequencies at which resonance is found that affect the force measuring system (see **7.1.2**). It is recommended that the maximum frequency should not exceed 25 % of the testing system's measurement bandwidth, (see **7.1.1**) for two pole filter systems, or 6 % for single pole filter systems.

NOTE This is to prevent amplitude errors exceeding 0.2 %.

If two proving devices are used (Method B), the same frequency range shall be used for the low compliance and the high compliance proving devices.

6.2.3 *Dynamic force range*

The peak values of force used for the dynamic calibration procedure shall lie within the statically calibrated force range of the dynamic testing system. The dynamic force range shall be either through zero, tension only, or compression only. Tension only dynamic calibrations are not valid in compression and vice versa. Through-zero calibrations verify both tension and compression.

NOTE 1 The peak values used should be within the working range of the calibration device.

NOTE 2 The dynamic force ranges used for the low compliance and the high compliance proving devices (Method B) can be different.

NOTE 3 The dynamic force range and the frequency might be limited by the power of the testing system.

6.2.4 *Load train*

When using a replica test-piece the fixtures and fittings employed for dynamic testing shall be used.

When Method B is used the calibration shall be carried out using the load train with the greatest mass used in dynamic testing.

NOTE The greatest mass load train will give the most conservative result, but the calibration is valid for all tools of lower mass. To increase the valid frequency range it is permissible to carry out a calibration with a load train of lower mass, however this needs to be identified on the calibration certificate. The results obtained are only valid for load trains of this or lower mass.

6.2.5 *Mounting of calibration device*

The calibration device shall be mounted in the load train and attached directly to the grip adjacent to the testing system loadcell.

7 Procedure

7.1 Initial checks

7.1.1 *Bandwidth*

Establish the bandwidth of the testing system instrumentation (see Note 1).

NOTE 1 To estimate the operational bandwidth of the testing system instrumentation a measurement can be made of the instrumentation's response to a step change in the input signal. The step change can be created by closing a shunt relay across the load cell bridge and recording the sudden change in force signal. An alternative method is to fracture a brittle test-piece. It is essential to capture the response at a sufficiently high sampling rate to ensure that an accurate measurement of the rise time can be made. The bandwidth, w, in hertz (Hz), is then calculated using equation (1):

$$w = \frac{0.35}{t_{10-90}} \quad (1)$$

where

t_{10-90} is the rise time between the 10 % and 90 % values of the step change in s.

NOTE 2 For further details see ASTM E1942-98 Standard Guide for Evaluating Data Acquisitions Systems Used in Cyclic Fatigue and Fracture Mechanics Testing [1].

7.1.2 *Frequency sweep*

Increase the frequency slowly in a continuous manner or in small steps from the minimum to the maximum of the frequency calibration range with each proving device mounted in the load train. Read or record the output of the calibration device and note any transient peaks indicating resonance. Reduce the range of frequencies to be calibrated to avoid the resonant frequencies thus determined. The resulting frequency range shall not span any resonance.

NOTE 1 It is recommended that the frequency sweep be performed in load control to ensure sufficient control resolution.

NOTE 2 To avoid problems due to resonance, testing systems can be calibrated over more than one frequency range.

7.2 Calibration procedure

7.2.1 *Static calibration of the calibration device with reference to the dynamic testing system*

7.2.1.1 Using the force range defined in **6.2.3** cycle the force between the selected upper and lower peaks at least three times, then calibrate the device to the testing system indicator by holding the force constant on the testing system and reading the output of the calibration device. Take readings at the following static force values:

i) upper peak force −5 % of force range;

ii) upper peak force;

iii) lower peak force +5 % of force range;

iv) lower peak force.

7.2.1.2 Repeat **7.2.1.1** twice to generate three sets of readings.

7.2.1.3 Repeat **7.2.1** and **7.2.1.2** for the second proving device (Method B).

7.2.1.4 For each peak, calculate the coefficients of the straight line, which joins the two adjacent values to give the relationship between the calibration device output and the testing system indicator.

7.2.2 *Dynamic calibration of dynamic testing system*

7.2.2.1 Take peak readings from the force indicator of the testing system and from the calibration device at five increasing frequencies approximately equally distributed over the range and at four decreasing frequencies approximately mid way between these frequencies. Allow the testing system to settle at each new frequency before taking the reading.

7.2.2.2 Repeat **7.2.2.1** for the second proving device (Method B).

8 Calculation of results

8.1 Method

8.1.1 Convert the calibration device reading at each dynamic peak value to an equivalent testing system indicator value by using the coefficients determined in **7.2.1.4**.

8.1.2 Calculate the dynamic indication error for both upper and lower peaks at each frequency by subtracting the peak value indicated by the testing system from the value determined in **8.1.1**.

8.2 Conversion function (Method A)

8.2.1 If the errors calculated in **8.1.2** do not exceed 1 % of force range a conversion function is not required. For errors between 1 % and 5 % a conversion function shall be derived as described in **8.2.2**. Over the range where errors exceed 5 % the testing system shall be deemed to have failed calibration.

8.2.2 Correction factors, (C), shall be calculated according to equation (2):

$$C = \frac{F_r}{F_i} \tag{2}$$

where

F_r is the dynamic force range measured by the replica test-piece at a given frequency;

F_i is the dynamic force range indicated by the dynamic testing system at the same frequency.

8.2.3 The conversion function can be expressed either as a curve by plotting the correction factors, (C), against frequency (see Figure 1) or as a best fit second order polynomial over the frequency range verified, using at least five contiguous data points.

NOTE The deviation between any data point and the conversion function should not exceed 0.005.

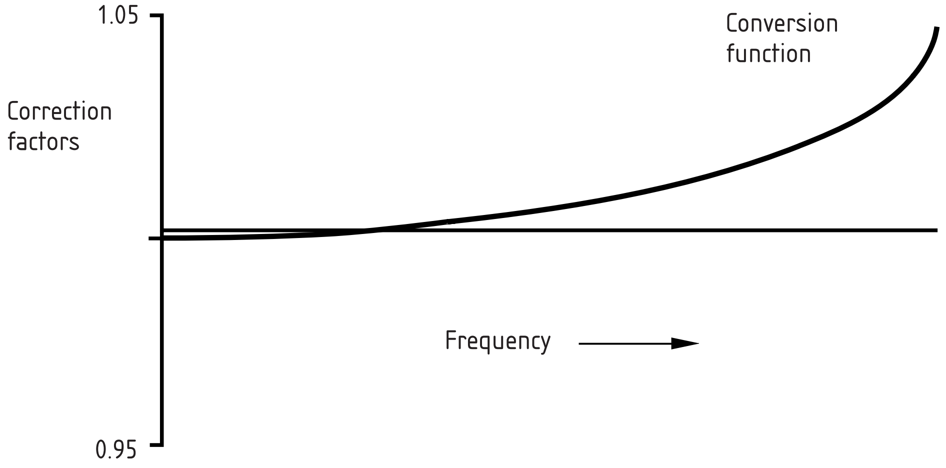

Figure 1 — Example of a conversion function

8.3 Calibration envelope (Method B)

The dynamic errors, determined using the high and low compliance proving devices, are plotted against frequency in order to define the calibrated range of the testing system (see Figure 2). The calibrated range of the testing system is that in which none of the errors exceeds 1 %.

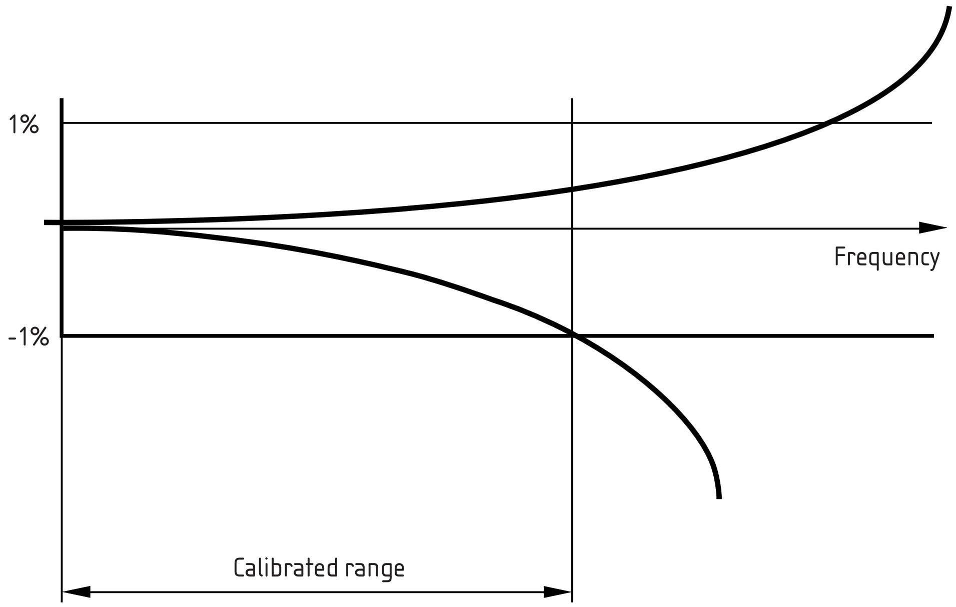

Figure 2 — Typical calibration envelope

9 Report

9.1 General information

The report shall state details of the following:

a) the force indicators and the indication range verified;

b) the range of frequency over which the calibration was attempted;

c) the testing system, including the manufacturer, model number, serial number and the identifiers for all components which make up the load train;

d) the mass of load train components between loadcell and test-piece;

e) the geometry, material and unique identifier for the replica test-piece;

f) the calibration devices, including the manufacturer and serial number;

g) the compliance of each proving device (Method B);

h) the standard to which static calibration of the testing system was performed (i.e. BS EN ISO 7500-1:1999), the class/grade, and date, when the static calibration was last performed;

i) the ambient temperature at the time of the test;

j) the name of the organization that carried out the calibration;

k) the date of calibration;

l) reference to this standard, i.e. BS 7935-1:2004.

9.2 Results of calibration

The report shall state the results of the calibration as follows:

a) the conversion function derived and its valid frequency range (Method A, where applicable);

b) any observations, notes or recommendations concerning the dynamic calibration;

c) the range of frequencies within which the dynamic indication errors are less than 1 % of the force range (Method B).

9.3 Re-calibration

The report shall include guidance concerning re-calibration, as given in Annex A.

Annex A (normative) Guidance on re-calibration to be supplied to the user

The report shall include the following guidance to the user concerning re-calibration of the testing machine:

a) Calibrate at intervals not exceeding 12 months.

b) Re-calibrate if any changes are made which affect the dynamic force indication, e.g. it has been moved or its mounting has been changed.

NOTE 1 The dynamic calibration remains valid if the loadcell is changed provided that the replacement is of identical design, capacity and mounting.

NOTE 2 It has been demonstrated that the testing system mounting is the major contributor towards inertia errors. The material, thickness and compliance of the floor, for example, can have a significant effect. For calibration purposes, the testing system mounting is considered to comprise the floor on which the system stands and any structure between the floor and the feet of the testing system feet (e.g. rubber pads).

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ASTM E1942-98, *Standard Guide for Evaluating Data Acquisitions Systems Used in Cyclic Fatigue and Fracture Mechanics Testing* [1].

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