

---

---

**Metallic materials — Verification of the  
alignment of fatigue testing machines**

*Matériaux métalliques — Vérification de l'alignement axial des  
machines d'essai de fatigue*

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

[ISO 23788:2012](https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012)

[https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-  
d0b41ce41eb0/iso-23788-2012](https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012)



## iTeh STANDARD PREVIEW (standards.iteh.ai)

ISO 23788:2012

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012>



### **COPYRIGHT PROTECTED DOCUMENT**

© ISO 2012

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing 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](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

Foreword .....	iv
Introduction .....	v
1 Scope .....	1
2 Normative references .....	1
3 Terms and definitions .....	1
4 Symbols .....	3
5 Measurement requirements .....	4
5.1 Testing machine .....	4
5.2 Alignment cell .....	4
5.3 Design and manufacturing .....	4
5.4 Machining .....	6
5.5 Inspection before attaching the strain gauges .....	6
5.6 Instrumentation with strain gauges .....	6
5.7 System checks .....	7
6 Alignment measurement calculations .....	7
6.1 General .....	7
6.2 Cylindrical alignment cell .....	7
6.3 Thick rectangular alignment cell .....	9
6.4 Thin rectangular alignment cell .....	9
6.5 Classification of machine alignment .....	9
7 Procedure for verification of machine alignment .....	10
7.1 Purpose and frequency .....	10
7.2 Procedure .....	10
8 Reporting .....	11
8.1 Basic information .....	11
8.2 Special information .....	12
Annex A (informative) Causes of specimen bending and misalignment in fatigue testing machines .....	17
Annex B (normative) Evaluating uncertainty in the alignment measurement .....	19
Annex C (informative) Method for measuring machine lateral stiffness .....	22
Annex D (informative) Three-strain gauge configuration .....	24
Annex E (informative) Determination of bending contribution due to inherent imperfections in a cylindrical alignment cell device .....	26
Annex F (informative) Numerical example .....	27
Annex G (normative) Alignment gauge — A method for qualitative assessment of alignment of test systems for cylindrical specimens .....	28
Bibliography .....	30

## 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 23788 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

## iTeh STANDARD PREVIEW (standards.iteh.ai)

[ISO 23788:2012](https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012)

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012>

## Introduction

Machine alignment in the context of this International Standard means the coincidence of the geometrical (loading) axes of the grips. Any departure from this ideal situation results in an angular and/or lateral offset (or misalignment) in the load train (see Annex A). Misalignment is manifested as an unwanted bending stress/strain field to exist in the test specimen or alignment measuring device (hereinafter “alignment cell”). The bending stress/strain field superimposes on the applied, presumed uniform, stress/strain field. In pure torsion testing, any misalignment results in a biaxial torsion plus bending stress/strain state.

Misalignment in the load train in axial fatigue test systems has been shown to influence significantly the fatigue test results (see References [1], [2] and [3]).

The main causes of bending due to misalignment are invariably a combination of

- poor coincidence of the centrelines of the grips, and
- inherent imperfections in the specimen or alignment cell itself.

The bending contribution due to the test machine ideally remains the same for every test specimen or alignment cell. The bending contribution due to the specimen or alignment cell varies from one device to another.

Recent research (see References [4] and [5]) has shown that no matter how carefully a specimen or an alignment cell device has been manufactured an inherent bending error always exists. Imperfections (i.e. eccentricity and angularity) arise from geometric asymmetry about the axial centreline in the device and other measurement errors relating to the chosen type, positioning and performance of the strain gauges. The device inherent bending error can be significant and sometimes even exceed that due to the machine misalignment.

In this International Standard, errors due to inherent imperfections in the alignment cell itself are eliminated. This is achieved by rotating the alignment device 180° about its longitudinal axis and subtracting its contribution from the overall maximum surface bending strain determined in the measurement. Different devices that are made of the same material and nominal dimensions should reasonably, therefore, produce the same alignment measurement results; see an example in Reference [2], Figure 10.

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

ISO 23788:2012

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012>

# Metallic materials — Verification of the alignment of fatigue testing machines

## 1 Scope

This International Standard describes a method for verifying the alignment in a testing machine using a strain-gauged measuring device. It is applicable to dynamic uniaxial tension/compression, pure torsion and combined tension/compression plus torsion fatigue testing machines for metallic materials.

The methodology outlined in this International Standard is generic and can be applied to static testing machines and in non-metallic materials testing.

## 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 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: tension/ compression testing machines — Verification and calibration of force-measuring system*

## 3 Terms and definitions (standards.iteh.ai)

For the purposes of this document, the following terms and definitions apply.

### 3.1 alignment

coincidence of the loading axes of the load train components, including the test specimen

NOTE Departure from such coincidence can introduce bending moments into the specimen.

### 3.2 alignment cell

carefully machined measuring device instrumented with strain gauges for use in verifying the alignment of a testing machine

### 3.3 alignment gauge

carefully machined mechanical device made of a split bar and a gauge for pass/fail checking of the correct alignment of the grips

### 3.4 average axial strain

$\varepsilon_0$

average longitudinal axial strain measured at the surface of the alignment cell by a set of strain gauges located in the same cross-sectional plane

NOTE The average axial strain represents the strain at the geometrical centre of the cross section.

### 3.5 load train

all the components between and including the crosshead and the actuator

NOTE The load train includes the specimen.

**3.6**  
**bending strain**

$\epsilon_b$   
difference between the local strain measured by a strain gauge and the average axial strain

NOTE Bending strain is a vector characterized by a magnitude, a direction and a discrete point of application. In general, it varies from point to point on the surface of the alignment cell.

**3.7**  
**machine alignment**

coincidence of the axes of the grips, which is characterized by the maximum bending strain component  $\epsilon_{b,max,mc}$

NOTE Machine misalignment is manifested by the existence of a lateral offset and/or an angular offset between the loading axes of the upper and lower grips.

**3.8**  
**machine aspect**

reference to the test machine's front, back, left and right

**3.9**  
**maximum bending strain**

$\epsilon_{b,max}$   
vector quantity with the largest bending strain magnitude in a given cross-sectional plane

NOTE Maximum bending strain vector is characterized by a magnitude, a direction and a discrete point of application.

**3.10**  
**percentage bending**

$\beta$   
maximum bending strain times 100 and divided by the average axial strain

iTeh STANDARD PREVIEW  
(standards.iteh.ai)

**3.11**  
**measurement plane**

cross-sectional plane in the alignment cell in which the transverse axes of a set of strain gauges are positioned

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ee41eb0/iso-23788-2012>

**3.12**  
**measurement orientations**

position of the alignment cell (0°, 90°, 180° and 270°), about its longitudinal axis, which defines the location of gauge 1 or a permanent mark on the alignment cell's surface, with respect to the front of the machine

NOTE The front of the machine is the R-direction.

**3.13**  
**parallel length**

$L_p$   
parallel portion of the reduced section of the alignment cell

**3.14**  
**proportional limit**

greatest stress that a material is capable of sustaining elastically, i.e. without any deviation from proportionality of stress to strain

**3.15**  
**R-direction**

fixed reference direction with respect to the frame of the testing machine

NOTE Typically, it is the direction from the centre towards the front of the machine.

**3.16**  
**strain gauge axial separation**

$L_g$   
axial distance on the alignment cell between the upper and lower measurement planes



**3.17****strain gauge transverse separation** $W_g$ 

transverse distance on the broad face of a thin rectangular alignment cell between the centres of the strain gauges

**4 Symbols**

For the purposes of this document, the following symbols apply.

<b>Symbol</b>	<b>Description</b>
$A_1 - A_4$	upper set of strain gauges
$B_1 - B_4$	lower set of strain gauges
$d$	minimum diameter of cylindrical alignment cell; inner diameter of alignment gauge
$D$	diameter at grip end of cylindrical alignment cell
$e$	eccentricity or lateral offset
$L_p$	parallel length
$L_g$	axial separation of strain gauges
$L_z$	overall length of alignment cell, alignment gauge or test specimen
$r$	fillet radius between the parallel length and the grip end of the alignment cell or test specimen
$t$	thickness of reduced section of rectangular alignment cell
$w$	width of reduced section of rectangular alignment cell
$W$	width at grip end of rectangular alignment cell
$w_g$	transverse separation of strain gauges
$B$	percentage bending
$\beta_{ac}$	percentage bending due to inherent imperfections in the alignment cell
$\beta_{mc}$	percentage bending due to machine misalignment
$\varepsilon_0$	average axial strain
$\varepsilon_1, \varepsilon_2, \text{etc.}$	readings of individual strain gauges (i.e. local strain)
$\varepsilon_b$	bending strain (combined value)
$\varepsilon_{b,ac}$	bending strain component due to inherent imperfections in the alignment cell
$\varepsilon_{b,mc}$	bending strain component due to machine misalignment
$\varepsilon_{b,max}$	maximum bending strain (combined value)
$\varepsilon_{b,max,ac}$	maximum bending strain component due to inherent imperfections in the alignment cell
$\varepsilon_{b,max,mc}$	maximum bending strain component due to machine misalignment
$\gamma$	angular offset

- $\theta_{ac}$  angle (clockwise where seen from above) of the location of  $\epsilon_{b,max,ac}$  with respect to gauge 1 (or a permanent mark on the alignment cell's surface)
- $\theta_{mc}$  angle (clockwise where seen from above) of the location of  $\epsilon_{b,max,mc}$  with respect to front of the machine (the R-direction)

## 5 Measurement requirements

### 5.1 Testing machine

The testing system shall have a force-measuring system comprising force transducer (load cell), conditioner and readout units. This system shall meet the requirements of ISO 7500-1.

NOTE 1 Class 1 requires that force indicated errors do not exceed  $\pm 1$  % of the reading over the verification range.

It is essential that the grips enable rotating the alignment cell  $180^\circ$  about its longitudinal axis. It shall also adequately enable repeatable positioning and gripping of the alignment cell with minimal variation in the misalignment (see Annex B).

It is recommended, but not essential, that the machine be equipped with means for adjusting the lateral and angular offsets of one part of the load train. It is also recommended to

- minimize the number of components of which these gripping devices are composed in order to reduce the number of mechanical interfaces, and
- maximize the lateral stiffness of the fatigue testing machine in order to reduce the effects of any so-called reversed bending on fatigue test results in tests involving reversed tension-compression loading (see Reference [1]).

NOTE 2 See Annex C for a method for measuring machine lateral stiffness.

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012>

### 5.2 Alignment cell

Alignment measurement can be slightly affected by the stiffness of the alignment cell used in the measurement (see Figure 13 in Reference [2]); the lower the stiffness of the device, the higher its measurement sensitivity of machine alignment. A good alignment cell should also be sufficiently robust to last and enable successive usage over a long period of time (i.e. years). Care should be taken to ensure both requirements are adequately fulfilled.

A suitable material for an alignment cell should ideally have:

- a sufficiently high linear elastic range;
- a high degree of metallurgical stability;
- freedom from appreciable residual stress to ensure dimensional stability;
- good oxidation resistance.

Fully tempered steels, e.g. alloy steels with 0,2 % proof stress in the order of 1 000 MPa, are ideal candidate materials for alignment cells (see References [3] and [4]). High-strength aluminium alloys, such as 7075-T6, are amongst suitable alternatives.

### 5.3 Design and manufacturing

#### 5.3.1 Design

The alignment cell shall have the same overall length (but not necessarily the same gauge length and cross-sectional area) as the fatigue test specimen. It shall fit into the grips in the same way the fatigue test specimen does so that use of special adaptors is avoided. For cylindrical devices, the diameter,  $d$ , shall be no more

than 10 mm or the fatigue test specimen's diameter, whichever is the greater. The recommended standard diameters are 5 mm, 7,5 mm and 10 mm.

Tables 1, 2 and 3 show the recommended standard proportions. Smaller cross-section dimensions than those shown in the tables may be used subject to availability of suitable strain gauges. Figures 1 and 2 show the requirements for concentricity, straightness and parallelism (i.e. machining tolerances for surfaces which affect the alignment) for the basic alignment cell shapes.

Other geometries and profiles are permissible, provided the principal requirements of this International Standard are observed. Significant variations in dimensions can, however, preclude meaningful comparison with measurements from the recommended standard cells. For recommendations on other geometries and design of grip ends, see Reference [4].

### 5.3.2 Dimensions of alignment cells of circular cross-sections

See Table 1 and Figure 1.

**Table 1 — Nominal dimensions for alignment cells of circular cross-sections**

Dimension mm	Recommendation
$d$	5, 7,5 and 10
$L_p$	$2,5d$
$r$	$\geq 2d$
$D$	$D$ (test specimen)
$L_z$	$L_z$ (test specimen)
Surface roughness of reduced section: 0,8 $\mu\text{m}$ to 1,6 $\mu\text{m}$ .	

ISO 23788:2012

[https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-](https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-4007160750-23788-2012)

### 5.3.3 Dimensions of alignment cells of thick rectangular cross-sections

See Table 2 and Figure 2.

**Table 2 — Nominal dimensions for alignment cells of thick rectangular cross-sections**

Dimension mm	Recommendation
$t$	5, 7,5 and 10
$w$	$\geq t$
$L_p$	$\geq 2,5t$
$r$	$2t$ to $8t$
$W$	$W$ (test specimen)
$L_z$	$L_z$ (test specimen)
Surface roughness of reduced section: 0,8 $\mu\text{m}$ to 1,6 $\mu\text{m}$ .	

### 5.3.4 Dimensions of alignment cells of thin rectangular cross-sections

See Table 3 and Figure 2.

**Table 3 — Nominal dimensions for alignment cells of thin rectangular cross-sections**

Dimension mm	Recommendation
$t$	2, 3, 4
$w$	$\geq 5t$
$L_p$	$\geq 2,5t$
$r$	2t to 8t
$W$	$W$ (test specimen)
$L_z$	$L_z$ (test specimen)
Surface roughness of reduced section: 0,8 $\mu\text{m}$ to 1,6 $\mu\text{m}$ .	

### 5.4 Machining

Small and decreasing cuts with an adequate supply of coolant shall be used for finishing so that the metallurgical structure and properties are not affected and that undue residual stresses are not induced in the cell material. For effective bonding of the strain gauges, the optimum surface finish for the alignment cell shall be in the range 0,8  $\mu\text{m}$  to 1,6  $\mu\text{m}$  (see Reference [4]).

NOTE Surface roughness for fatigue test specimens are usually within 0,2  $\mu\text{m}$  to 0,4  $\mu\text{m}$ .

### 5.5 Inspection before attaching the strain gauges

The alignment cell shall be carefully inspected (with instruments, such as an optical shadowgraph or comparator) and all the critical dimensions and the associated geometrical tolerances confirmed prior to attachment of the strain gauges to ensure that all the geometrical requirements are met. After the strain gauges are applied, it is no longer possible to inspect the alignment cell with these methods.

<https://standards.iteh.ai/catalog/standards/sist/261d1d17-fa79-4d55-856b-d0b41ce41eb0/iso-23788-2012>

### 5.6 Instrumentation with strain gauges

An array of eight strain gauges (arranged in two sets of four) shall be numbered and positioned as shown in Figure 3 (see References [4] and [5]). For cylindrical alignment cells [see Figure 3 a)], the strain gauges shall be equally spaced, 90° apart, around the circumference of the alignment cell. The configuration shown in Figure 3 b) is suitable for rectangular alignment cells with a width to thickness ratio  $w:t < 3$ . For higher  $w:t$  values, the gauges may be placed in pairs of back-to-back sensors and equidistant from the centreline of the alignment cell as shown in Figure 3 c). The strain gauges shall all be matched, i.e. from the same manufacturer's batch. It is recommended they have active lengths of approximately 0,1  $L_p$  or less.

The alignment measurement parameters in this International Standard are determined from the ratios of the measured strains, and they should not, therefore, be affected by temperature changes. Use of self-temperature-compensated strain gauges matched to the alignment cell material is recommended, especially if accurate determination of the absolute axial average strain, such as in modulus measurement, is also needed.

With reference to Figure 3, Table 4 gives the locations for positioning the strain gauges on the surface of the alignment cell.

**Table 4 — Locations of strain gauges**

Dimension	Requirement
$L_g$	$= 0,75 L_p$
$w_g$	$= 0,75 w$

NOTE The distance  $L_g = 0,75 L_p$  represents the maximum feasible separation to minimize effects due to stress concentration associated with the change of section at the ends of the alignment cell's parallel length.