

INTERNATIONAL

国际的

ISO 6892-1

ISO 6892-1

STANDARD

Third edition

第三版

2019-11

Metallic materials — Tensile testing — Part 1: Method of test at room temperature

金属材料 — 拉伸试验 — 第 1 部分:室温试验方法

Matériaux métalliques — Essai de traction —

金属材料 — 拉伸试验 —

Partie 1: Méthode d'essai à température ambiante Reference number ISO 6892-1:2019(E) © ISO 2019 (C) ISO 2019

第 1 部分:室温试验方法 参考编号 ISO 6892-1:2019(E) © ISO 2019 (C) ISO 2019



All rights reserved. Unless otherwise specified, or required in the context of its implementation, 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.

保留所有权利。除非另有规定，或在其实施的背景下有要求，否则未经事先书面许可，本出版物的任何部分均不得以任何形式或通过任何手段(包括影印、在互联网或内联网上发布)进行复制或其他利用。可向以下地址的 ISO 或请求者所在国家的 ISO 成员机构请求许可。

ISO copyright office

ISO 版权办公室

CP 401 · Ch . de Blandonnet 8

CP 401 · Ch . 布兰多内 8 号

CH-1214 Vernier, Geneva

瑞士日内瓦韦尔尼 CH-1214

Phone: +41 22 749 01 11

电话:+41 22 749 01 11

Fax: +41 22 749 09 47

传真:+41 22 749 09 47

Email: copyright@iso.org

电子邮件:copyright@iso.org

Website: www.iso.org

网站:www.iso.org

Published in Switzerland

在瑞士出版

Contents Page

目录

Foreword _ V

前言 _ V

Introduction vi

引言 六

1 Scope 1

1 范围	1
2 Normative references	1
2 规范性引用文件	1
3 Terms and definitions	1
3 术语和定义	1
4 Symbols	6
4 符号	6
5 Principle	8
5 原理	8
6 Test pieces	8
6 试样	8
6.1 Shape and dimensions	8
6.1 形状和尺寸	8
6.1.1 General.	8
6.1.1 一般规定	8
6.1.2 Machined test pieces	9
6.1.2 加工试样	9
6.1.3 Unmachined test pieces.	9
6.1.3 未加工试样	9
6.2 Types.	9
6.2 类型	9
6.3 Preparation of test pieces	10
6.3 试样制备	10
7 Determination of original cross-sectional area	10
7 原始横截面积的测定	10
8 Original gauge length and extensometer gauge length	10
8 原始标距长度和引伸计标距长度	10

8.1 Choice of the original gauge length	10
8.1 原始标距长度的选择	10
8.2 Marking the original gauge length a	10
8.2 标记原始标距长度 a	10
8.3 Choice of the extensometer gauge length	11
8.3 引伸计标距长度的选择	11
9 Accuracy of testing apparatus	11
9 试验设备的精度	11
10 Conditions of testing	11
10 试验条件	11
10.1 Setting the force zero point	11
10.1 设置力的零点	11
10.2 Method of gripping	11
10.2 夹持方法	11
10.3 Testing rates	12
10.3 试验速率	12
10.3.1 General information regarding testing rates	12
10.3.1 关于试验速率的一般信息	12
10.3.2 Testing rate based on strain rate (method A)	12
10.3.2 基于应变率的试验速率(方法 A)	12
10.3.3 Testing rate based on stress rate (method B)	14
10.3.3 基于应力率的试验速率(方法 B)	14
10.3.4 Report of the chosen testing conditions	15
10.3.4 所选试验条件的报告	15
11 Determination of the upper yield strength	16
11 上屈服强度的测定	16
12 Determination of the lower yield strength	16

12 下屈服强度的测定。	16
13 Determination of proof strength, plastic extension	16
13 规定塑性延伸强度的测定	16
14 Determination of proof strength, total extension	17
14 规定总延伸强度的测定	17
15 Method of verification of permanent set strength	17
15 永久变形强度验证方法	17
16 Determination of the percentage yield point extension	17
16 屈服点伸长率的测定	17
17 Determination of the percentage plastic extension at maximum force.	17
17 最大力下塑性伸长率的测定。	17
18 Determination of the percentage total extension at maximum force	18
18 最大力下总伸长率的测定	18
19 Determination of the percentage total extension at fracture	18
19 断裂时总伸长率的测定	18
20 Determination of percentage elongation after fracture.	18
20 断裂后伸长率的测定。	18
21 Determination of percentage reduction of area	19
21 断面收缩率的测定	19
22 Test report.	20
22 试验报告。	20
23 Measurement uncertainty	20
23 测量不确定度	20
23.1 General	20
23.1 总则	20
23.2 Test conditions	21
23.2 试验条件	21

23.3 Test results. 21

23.3 试验结果。21

Annex A (informative) Recommendations concerning the use of computer-controlled

附录 A(资料性)关于使用计算机控制的

tensile testing machines 34

拉伸试验机的建议 34

Annex B (normative) Types of test pieces to be used for thin products: sheets, strips, and

附录 B(规范性)用于厚度在 0.1 毫米至 3 毫米之间的薄产品的试件类型:薄板、薄带和

flats between 0,1 mm and 3 mm thick. 40

扁材。40

Annex C (normative) Types of test pieces to be used for wire, bars, and sections with a

附录 C(规范性附录)用于具有特定规格的线材、棒材和型材的试件类型

diameter or thickness of less than 4 mm 43

直径或厚度小于 4 mm 43

Annex D (normative) Types of test pieces to be used for sheets and flats of thickness equal

附录 D(规范性附录)厚度相等的板材和扁材所用试样的类型

to or greater than 3 mm and wire, bars, and sections of diameter or thickness equal

达到或大于 3 mm 且直径或厚度相等的线材、棒材和型材

to or greater than 4 mm 44

达到或大于 4 mm 44

Annex E (normative) Types of test pieces to be used for tubes 48

附录 E(规范性附录)用于管材的试件类型 48

Annex F (informative) Estimation of the crosshead separation rate in consideration of

附录 F(资料性) 考虑到的十字头分离速率的估算

the stiffness (or compliance) of the testing equipment 50

测试设备 50 的刚度(或柔度)

Annex G (normative) Determination of the modulus of elasticity of metallic materials using

附录 G(规范性附录) 使用……测定金属材料的弹性模量

a uniaxial tensile test. 52

单轴拉伸试验。52

Annex H (informative) Measuring the percentage elongation after fracture if the specified

附录 H(资料性) 测定规定条件下的断裂后伸长率百分比

value is less than 5 %. 61

数值小于 5%。61

Annex I (informative) Measurement of percentage elongation after fracture based

附录 I(资料性) 基于断裂后伸长率百分比的测量

on subdivision of the original gauge length 62

关于原始标距长度 62 的细分

Annex J (informative) Determination of the percentage plastic elongation without necking,

附录 J(资料性) 无缩颈塑性伸长率的测定

A_{WD} , for long products such as bars, wire, and rods 64

A_{WD} , 对于棒材、线材和杆材等长材产品 64

Annex K (informative) Estimation of the uncertainty of measurement 65

附录 K(资料性) 测量不确定度的评定 65

Annex L (informative) Precision of tensile testing — Results from interlaboratory programmes μ (69

附录 L(资料性) 拉伸试验的精密度——实验室间计划的结果 μ (69

Bibliography 76

参考文献 76

Foreword

前言

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.

ISO(国际标准化组织)是一个由各国标准化机构(ISO 成员机构)组成的全球性联合会。制定国际标准的工作通常由 ISO 技术委员会开展。对已成立技术委员会的主题感兴趣的每个成员机构都有权在该委员会中派代表。与 ISO 保持联络的国际组织,包括政府组织和非政府组织,也参与这项工作。ISO 在所有电工标准化事项上与国际电工委员会(IEC)密切合作。

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 (see www.iso.org/directives).

制定本文件所使用的程序以及拟用于其进一步维护的程序在 ISO/IEC 导则第 1 部分中有所描述。尤其应注意 ISO 不同类型文件所需的不同批准标准。本文件是根据 ISO/IEC 导则第 2 部分的编辑规则起草的(见 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 (see www.iso.org/patents).

请注意,本文件的某些要素可能涉及专利权。ISO 不负责识别任何或所有此类专利权。在文件制定过程中识别出的任何专利权细节将在引言中和/或 ISO 收到的专利声明列表中列出(见 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.

本文件中使用的任何商品名称仅为方便用户提供信息,不构成认可。

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information

about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

关于标准的自愿性质、ISO 特定术语和与合格评定相关的表述的含义，以及 ISO 在《贸易技术壁垒协定》(TBT)中遵守世界贸易组织(WTO)原则的信息，请见 www.iso.org/iso/foreword.html。

This document was prepared by Technical Committee ISO/TC 164, Mechanical testing of metals, Subcommittee SC 1, Uniaxial testing.

本文件由 ISO/TC 164 金属材料力学性能试验技术委员会 SC 1 单轴试验分委员会编制。

This third edition cancels and replaces the second edition (ISO 6892-1:2016), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

本第三版取消并取代第二版(ISO 6892-1:2016)，本版为小幅修订版。与上一版相比的变化如下：

— correction of the title of a standard in Clause 2;

—— 第 2 条中一个标准标题的更正；

- correction of the designation "coefficient of determination" ("coefficient of determination" instead of "coefficient of correlation");

—— “决定系数” (“coefficient of determination”，而非“相关系数” “coefficient of correlation”)表述的更正；

— correction of Formula (1);

—— 公式(1)的更正；

— wording in 10.3.2.1;

—— 10.3.2.1 中的措辞；

— wording in the key of Figure 9;

—— 图 9 标题中的措辞；

— wording in Table B.2;

— 表 B.2 中的措辞；

— wording in Table D.3;

— 表 D.3 中的措辞；

— correction of the references.

— 参考文献的更正。

A list of all parts in the ISO 6892 series can be found on the ISO website.

ISO 6892 系列所有部分的列表可在 ISO 网站上找到。

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

关于本文件的任何反馈或问题应提交给用户所在国家的标准机构。这些机构的完整列表可在 www.iso.org/members.html 上找到。

Introduction

引言

During discussions concerning the speed of testing in the preparation of ISO 6892, it was decided to recommend the use of strain rate control in future revisions.

在制定 ISO 6892 过程中关于试验速度的讨论期间，决定在未来修订版中推荐使用应变速率控制。

In this document, there are two methods of testing speeds available. The first, method A, is based on strain rates (including crosshead separation rate) and the second, method B, is based on stress rates. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results. Therefore, and out of the fact that often the strain rate sensitivity of the materials is not known, the use of method A is strongly recommended.

本文件中有两种试验速度方法可供使用。第一种，方法 A，基于应变速率(包括十字头分离速率)，第二种，方法 B，基于应力速率。方法 A 旨在尽量减少在确定应变速率敏感参数时试验速率的变化，并尽量减少试验结果的测量不确定度。因此，鉴于通常材料的应变速率敏感性未知，强烈推荐使用方法 A。

NOTE In what follows, the designations "force" and "stress" or "extension", "percentage extension", and "strain", respectively, are used on various occasions (as figure axis labels or in explanations for the determination of different properties). However, for a general description or point on a curve, the designations "force" and "stress" or "extension", "percentage extension", and "strain", respectively, can be interchanged.

注 在以下内容中，“力”和“应力”或“伸长”、“伸长率”和“应变”的表述分别在不同场合使用(如图形坐标轴标签或在确定不同性能的解释中)。然而，对于

一般描述或曲线上的点，“力”和“应力”或“伸长”、“伸长率”和“应变”的表述分别可以互换。

Metallic materials — Tensile testing — Part 1: Method of test at room temperature

金属材料 拉伸试验 第 1 部分:室温试验方法

1 Scope

1 范围

This document specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at room temperature.

本文件规定了金属材料拉伸试验的方法，并定义了可在室温下测定的力学性能。

NOTE Annex A contains further recommendations for computer controlled testing machines.

注 附录 A 包含了对计算机控制试验机的进一步建议。

2 Normative references

2 规范性引用文件

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

下列文件在文中的引用方式使得其部分或全部内容构成本文件的要求。对于注明日期的引用文件，仅引用的版本适用。对于未注明日期的引用文件，引用文件的最新版本(包括任何修订)适用。

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

ISO 7500-1, 金属材料 静态单轴试验机的校准和验证 第 1 部分:拉伸/压缩试验机测力系统的验证和校准

ISO 9513, Metallic materials - Calibration of extensometer systems used in uniaxial testing

ISO 9513, 金属材料——单轴试验中引伸计系统的校准

3 Terms and definitions

3 术语和定义

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

就本文件而言，适用以下术语和定义。

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

ISO 和 IEC 在以下网址维护用于标准化的术语数据库:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— ISO 在线浏览平台:可在 <https://www.iso.org/obp> 获取

— IEC Electropedia: available at <http://www.electropedia.org/>

— IEC 电子百科全书:可在 <http://www.electropedia.org/> 获取

3.1

gauge length

标距长度

L

length of the parallel portion of the test piece on which elongation is measured at any moment during the test

试验件平行部分的长度，在试验过程中的任何时刻，在此长度上测量伸长量

3.1.1

original gauge length

原始标距长度

L_0 length between gauge length (3.1) marks on the test piece measured at room temperature before the test

L_0 试验前在室温下测量的试验件上标距长度(3.1)标记之间的长度

3.1.2

final gauge length after fracture

断裂后的最终标距长度

$$L_u$$

length between gauge length (3.1) marks on the test piece measured after rupture, at room temperature, the two pieces having been carefully fitted back together so that their axes lie in a straight line

在室温下破裂后测量的试验件上标距长度(3.1)标记之间的长度，将两块试验件小心地重新拼接在一起，使它们的轴线位于一条直线上

3.2

parallel length

平行长度

$$L_c$$

length of the parallel reduced section of the test piece

试验件平行缩减段的长度

Note 1 to entry: The concept of parallel length is replaced by the concept of distance between grips for

条目注释 1:对于未加工的试验件，平行长度的概念被夹头之间的距离概念所取代。

unmachined test pieces.

未加工的试验件。

3.3

elongation

伸长率

increase in the original gauge length (3.1.1) at any moment during the test

在试验过程中任一时刻原始标距长度(3.1.1)的增加量

3.4

percentage elongation

伸长百分比

elongation (3.3) expressed as a percentage of the original gauge length (3.1.1)

伸长率(3.3)，以原始标距长度(3.1.1)的百分比表示

3.4.1

percentage permanent elongation

永久伸长百分比

increase in the original gauge length (3.1.1) of a test piece after removal of a specified stress, expressed as a percentage of the original gauge length (3.1.1)

去除规定应力后，试样原始标距长度(3.1.1)的增加量，以原始标距长度(3.1.1)的百分比表示

3.4.2

percentage elongation after fracture

断裂后伸长百分比

A

permanent elongation (3.3) of the gauge length after fracture ($L_u - L_o$), expressed as a percentage of the original gauge length (3.1.1)

断裂后($L_u - L_o$)标距长度的永久伸长率(3.3), 以原始标距长度(3.1.1)的百分比表示

Note 1 to entry: For further information, see [8.1.

条目注释 1:如需更多信息, 请参见[8.1。

3.5

extensometer gauge length

引伸计标距长度

L_e

initial gauge length of the extensometer used for measurement of extension (3.6)

用于测量伸长(3.6)的引伸计的初始标距长度

Note 1 to entry: For the determination of several properties which are based (partly or complete) on extension, e. g. R_p , A_e or A_g , the use of an extensometer is mandatory.

条目注释 1:对于部分或完全基于伸长率测定的几种性能, 例如 R_p , A_e 或 A_g , 必须使用引伸计。

Note 2 to entry: For further information, see [8,3.

条目注释 2:如需更多信息, 请参见[8,3。

3.6

extension

伸长

increase in the extensometer gauge length (3.5), at any moment during the test

在试验过程中任一时刻引伸计标距长度(3.5)的增加量

3.6.1

percentage extension

伸长百分比

strain e extension (3.6) expressed as a percentage of the extensometer gauge length (3.5) Note 1 to entry: e is commonly called engineering strain.

应变 e 伸长率(3.6)，以引伸计标距长度(3.5)的百分比表示 条目注释 1: e 通常称为工程应变。

3.6.2

percentage permanent extension increase in the extensometer gauge length (3.5), after removal of a specified stress (3.10) from the test piece, expressed as a percentage of the extensometer gauge length

永久伸长率的百分比 从试验件上去除规定应力(3.10)后，引伸计标距长度(3.5)的增加量，以引伸计标距长度的百分比表示

3.6.3 percentage yield point extension

3.6.3 屈服点伸长率百分比

A_e

<discontinuous yielding materials> extension (3.6) between the start of yielding and the start of uniform work-hardening, expressed as a percentage of the extensometer gauge length (3.5)

<不连续屈服材料> 从开始屈服到开始均匀加工硬化之间的伸长率(3.6)，以引伸计标距长度(3.5)的百分比表示

Note 1 to entry: See Figure 7.

条目注释 1:见图 7。

3.6.4 percentage total extension at maximum force

3.6.4 最大力下的总伸长率百分比

$$A_{gt}$$

total extension (3.6) (elastic extension plus plastic extension) at maximum force, expressed as a percentage of the extensometer gauge length (3.5)

最大力下的总伸长率(3.6)(弹性伸长率加塑性伸长率)，以引伸计标距长度(3.5)的百分比表示

Note 1 to entry: See Figure 1.

条目注释 1:见图 1。

3.6.5

percentage plastic extension at maximum force

最大力下的塑性伸长率百分比

A_g plastic extension (3.6) at maximum force, expressed as a percentage of the extensometer gauge length (3.5) Note 1 to entry: See Figure 1.

A_g 最大力下的塑性伸长率(3.6)，以引伸计标距长度(3.5)的百分比表示 条目注释 1: 见图 1。

3.6.6 percentage total extension at fracture

3.6.6 断裂时的总伸长率百分比

$$A_t$$

total extension (3.6) (elastic extension plus plastic extension) at the moment of fracture, expressed as a percentage of the extensometer gauge length (3.5) Note 1 to entry: See Figure 1. 3.7 testing rate rate (resp. rates) used during the test 3.7.1 strain rate $\dot{e}_L$ increase of strain, measured with an extensometer, in extensometer gauge length (3.5), per time 3.7.2

断裂瞬间的总伸长率(3.6)(弹性伸长率加塑性伸长率)，以引伸计标距长度(3.5)的百分比表示 条目注释 1:见图 1。3.7 试验速率 试验期间使用的速率(或多个速率) 3.7.1 应变速率 $\dot{e}_L$ 用引伸计测量的引伸计标距长度(3.5)中应变随时间的增加量 3.7.2

estimated strain rate over the parallel length

平行长度上的估计应变速率

$$e_L$$

value of the increase of strain over the parallel length (3.2) of the test piece per time based on the crosshead separation rate (3.7.3) and the parallel length of the test piece

基于十字头分离速率(3.7.3)和试验件的平行长度，试验件平行长度(3.2)上应变随时间的增加量的值

3.7.3 crosshead separation rate

3.7.3 十字头分离速率

$$v_c$$

displacement of the crossheads per time

十字头的位移随时间的变化

3.7.4

stress rate

应力速率

R

increase of stress (3.10) per time

应力随时间的增加量(3.10)

Note 1 to entry: Stress rate is only used in the elastic part of the test (method B) (see also 10.3.3).

条目注释 1:应力速率仅用于试验的弹性部分(方法 B)(另见 10.3.3)。

3.8 percentage reduction of area

3.8 断面收缩率

Z

maximum change in cross-sectional area which has occurred during the test ($S_0 - S_u$), expressed as a percentage of the original cross-sectional area, S_0 :

试验期间发生的最大横截面积变化量 ($S_0 - S_u$), 以原始横截面积 S_0 的百分比表示:

$$Z = \frac{S_0 - S_u}{S_0} \cdot 100$$

3.9 Maximum force

3.9 最大力

3.9.1

maximum force

最大力

F_m

<materials displaying no discontinuous yielding> highest force that the test piece withstands during the test

<无明显屈服现象的材料> 试验期间试样承受的最大力

3.9.2

maximum force

最大力

$$F_m$$

<materials displaying discontinuous yielding> highest force that the test piece withstands during the test after the beginning of work-hardening

<有明显屈服现象的材料> 加工硬化开始后试验期间试样承受的最大力

Note 1 to entry: For materials which display discontinuous yielding, but where no work-hardening can be established, F_m is not defined in this document [see footnote to Figure 8 c)].

条目注释 1:对于有明显屈服现象但无法确定加工硬化的材料, 本文件未定义 F_m [见图 8 c) 的脚注]。

Note 2 to entry: See Figure 8 a) and b).

条目注释 2:见图 8 a) 和 b)。

3.10

stress

应力

$$R$$

at any moment during the test, force divided by the original cross-sectional area, S_0 , of the test piece

在试验期间的任何时刻, 力除以试样的原始横截面积 S_0

Note 1 to entry: All references to stress in this document are to engineering stress.

条目注释 1:本文件中所有对应力的引用均指工程应力。

3.10.1

tensile strength

抗拉强度

$$R_m$$

stress (3.10) corresponding to the maximum force (3.9.2)

对应于最大力(3.9.2)的应力(3.10)

3.10.2

yield strength

屈服强度

when the metallic material exhibits a yield phenomenon, stress (3.10) corresponding to the point reached during the test at which plastic deformation occurs without any increase in the force

当金属材料出现屈服现象时，试验过程中达到的点所对应的应力(3.10)，在该点发生塑性变形且力不再增加

3.10.2.1

upper yield strength

上屈服强度

$$R_{eH}$$

maximum value of stress (3.10) prior to the first decrease in force

力首次下降之前应力(3.10)的最大值

Note 1 to entry: See Figure 2.

条目注释 1:见图 2。

3.10.2.2

lower yield strength

下屈服强度

$$R_{eL}$$

lowest value of stress (3.10) during plastic yielding, ignoring any initial transient effects

塑性屈服期间应力(3.10)的最低值，忽略任何初始瞬态效应

Note 1 to entry: See Figure 2.

条目注释 1:见图 2。

3.10.3

proof strength, plastic extension

规定强度，塑性延伸

$$R_p$$

stress (3.10) at which the plastic extension (3.6) is equal to a specified percentage of the extensometer gauge length (3.5)

塑性延伸(3.6)等于引伸计标距长度(3.5)规定百分比时的应力(3.10)

Note 1 to entry: Adapted from ISO/TR 25679:2005, "proof strength, non-proportional extension".

条目注释 1:改编自 ISO/TR 25679:2005，“规定强度，非比例延伸”。

Note 2 to entry: A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{p0,2}$.

条目注释 2:下标添加后缀以表示规定百分比，例如 $R_{p0,2}$ 。

Note 3 to entry: See Figure 3.

条目注释 3:见图 3。

3.10.4

proof strength, total extension

规定强度，总延伸

$$R_t$$

stress (3.10) at which total extension (3.6) (elastic extension plus plastic extension) is equal to a specified percentage of the extensometer gauge length (3.5)

总延伸(3.6)(弹性延伸加塑性延伸)等于引伸计标距长度(3.5)规定百分比时的应力(3.10)

Note 1 to entry: A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{t0,5}$.

条目注释 1:下标后添加一个后缀以表示规定的百分比，例如 $R_{t0,5}$ 。

Note 2 to entry: See Figure 4.

条目注释 2:见图 4。

3.10.5

permanent set strength

永久变形强度

$$R_r$$

stress (3.10) at which, after removal of force, a specified permanent elongation (3.3) or extension (3.6), expressed respectively as a percentage of original gauge length (3.1.1), or extensometer gauge length (3.5), has not been exceeded

在去除力之后，未超过规定的永久伸长率(3.3)或伸长量(3.6)时的应力(3.10)，永久伸长率或伸长量分别以原始标距长度(3.1.1)或引伸计标距长度(3.5)的百分比表示

Note 1 to entry: A suffix is added to the subscript to indicate the specified percentage of the original gauge length, L_o , or of the extensometer gauge length, L_e , e.g. $R_{r0,2}$.

条目注释 1:下标后添加一个后缀以表示原始标距长度的规定百分比 L_0 或引伸计标距长度的规定百分比 L_e ，例如 $R_{r0,2}$ 。

Note 2 to entry: See Figure 5.

条目注释 2:见图 5。

3.11

fracture

断裂

phenomenon which is deemed to occur when total separation of the test piece occurs

当试件完全分离时被认为发生的现象

Note 1 to entry: Criteria for fracture for computer controlled tests are given in Figure A.2.

条目注释 1:计算机控制试验的断裂判据见图 A.2。

3.12

computer-controlled tensile testing machine

计算机控制拉伸试验机

machine for which the control and monitoring of the test, the measurements, and the data processing are undertaken by computer

由计算机进行试验控制、监测、测量和数据处理的机器

3.13 modulus of elasticity

3.13 弹性模量

$$E$$

quotient of change of stress ΔR and change of percentage extension Δe in the range of evaluation, multiplied by 100%

在评估范围内应力 ΔR 的变化与伸长率百分比 Δe 的变化之商，乘以 100%

$$E = \frac{\Delta R}{\Delta e} \cdot 100\%$$

Note 1 to entry: It is recommended to report the value in GPa rounded to the nearest 0,1 GPa and according to ISO 80000-1.

条目注释 1:建议以 GPa 为单位报告该值，四舍五入到最接近的 0.1 GPa，并符合 ISO 80000-1。

3.14

default value

默认值

lower or upper value for stress (3.10), respectively strain (3.6.1), which is used for the description of the range where the modulus of elasticity (3.13) is calculated

应力(3.10)或应变(3.6.1)的下限或上限值，用于描述计算弹性模量(3.13)的范围

3.15

coefficient of determination

决定系数

$$R^2$$

additional result of the linear regression which describes the quality of the stress-strain curve in the evaluation range

线性回归的附加结果，用于描述评估范围内应力 - 应变曲线的质量

Note 1 to entry: The used symbol R^2 is a mathematical representation of regression and is no expression for a squared stress value. 3.16

条目注释 1:所使用的符号 R^2 是回归的数学表示，并非平方应力值的表达式。3.16

standard deviation of the slope

斜率的标准偏差

$$S_m$$

additional result of the linear regression which describes the difference of the stress (3.10) values from the best fit line for the given extension (3.6.1) values in the evaluation range

线性回归的附加结果，用于描述评估范围内给定伸长率(3.6.1)值下应力(3.10)值与最佳拟合线的差值

3.17

relative standard deviation of the slope

斜率的相对标准偏差

$$S_{\text{Infrel}}$$

quotient of the standard deviation of the slope (3.16) and the slope in the evaluation range, multiplie by 100 %

斜率(3.16)的标准偏差与评估范围内斜率的商，乘以 100%

$$S_{m(\text{rel})} = \frac{S_m}{E} \cdot 100\%$$

4 Symbols

4 符号

The symbols used in this document and corresponding designations are given in Table 1.

本文档中使用的符号及相应名称见表 1。

Table 1 — Symbols and designations

表 1 — 符号和名称

Symbol	Unit	Designation
Test piece		
a_0, T^3	mm	original thickness of a flat test piece or wall thickness of a tube
b_0	mm	original width of the parallel length of a flat test piece or average width of the longi- tudinal strip taken from a tube or width of flat wire
d_0	mm	original diameter of the parallel length of a circular test piece, or diameter of round wire or internal diameter of a tube
D_0	mm	original external diameter of a tube
L_0	mm	original gauge length
L'_0	mm	initial gauge length for determination of A_{wn} (see Annex I)
L_c	mm	parallel length
L_e	mm	extensometer gauge length
L_t	mm	total length of test piece
L_u	mm	final gauge length after fracture
L'_U	mm	final gauge length after fracture for determination of A_{wn} (see Annex J)
符号	单位	名称
试样		
a_0, T^3	毫米	扁平试样的原始厚度或管材的壁厚
b_0	毫米	扁平试样平行长度的原始宽度、取自管材的纵向条带的平均宽度或扁丝的宽度
d_0	毫米	圆形试样平行长度的原始直径、圆丝的直径或管材的内径

D_0	毫米	管材的原始外径
L_0	毫米	原始标距长度
L'_0	毫米	用于测定 A_{wn} 的初始标距长度(见附录 I)
L_c	毫米	平行长度
L_e	毫米	引伸计标距长度
L_t	mm	试样的总长度
L_u	毫米	断裂后的最终标距长度
L'_U	mm	用于测定 A_{wn} 的断裂后的最终标距长度(见附录 J)

a Symbol used in steel tube product standards.

钢管产品标准中使用的一个符号。

b $1\text{MPa} = 1\text{ N mm}^{-2}$.

The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

弹性模量的计算在附录 G 中说明。在确定规定强度时，无需使用附录 G 来确定应力-伸长率曲线弹性部分的斜率。

d In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).

d 在应力-伸长率曲线的弹性部分，斜率值不一定代表弹性模量。如果使用最佳条件(见附录 G)，该值可能与弹性模量值非常接近。

CAUTION — The factor 100 is necessary if percentage values are used.

注意 — 如果使用百分比值，系数 100 是必要的。

Table 1 (continued)

表 1(续)

Symbol	Unit	Designation
--------	------	-------------

S_0	mm ²	original cross-sectional area of the parallel length
S_u	mm ²	minimum cross-sectional area after fracture
k	-	coefficient of proportionality (see 6.1.1)
Z	%	percentage reduction of area
Elongation		
A	%	percentage elongation after fracture (see 3.4.2)
A_{wn}	%	percentage plastic elongation without necking (see Annex J)
Extension		
e	%	extension
A_e	%	percentage yield point extension
A_g	%	percentage plastic extension at maximum force, F_m
A_{gt}	%	percentage total extension at maximum force, F_m
A_t	%	percentage total extension at fracture
ΔL_m	mm	extension at maximum force
ΔL_f	mm	extension at fracture
Rates		
e_{Le}	s ⁻¹	strain rate
$\dot{e}_{Lc}$	s ⁻¹	estimated strain rate over the parallel length
$\dot{R}$	MPa s ⁻¹	stress rate
v_c	mm s ⁻¹	crosshead separation rate
Force		
F_m	N	maximum force
Yield strength — Proof strength — Tensile strength		
R	MPa ^b	stress
R_{eff}	MPa	upper yield strength
R_{eL}	MPa	lower yield strength
R_m	MPa	tensile strength
R_n	MPa	proof strength, plastic extension
R_r	MPa	specified permanent set strength
R_t	MPa	proof strength, total extension
Modulus of elasticity — slope of the stress-percentage extension curve		
E	GPa	modulus of elasticity ^c
m	MPa	slope of the stress-percentage extension curve at a given moment of the test

m_E	MPa	slope of the elastic part of the stress-percentage extension curve ^d
R_1	MPa	lower stress value
R_2	MPa	upper stress value
- Symbol used in steel tube product standards. b $1\text{MPa} = 1\text{Nmm}^{-2}$. The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength. ^d In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).		
符号	单位	名称
S_0	mm^2	平行长度的原始横截面积
S_u	平方毫米	断裂后的最小横截面积
k	-	比例系数(见 6.1.1)
Z	%	断面收缩率
伸长率		
A	%	断裂后伸长率(见 3.4.2)
A_{wn}	%	无缩颈塑性伸长率(见附录 J)
延伸		
e	%	延伸
A_e	%	屈服点延伸率
A_g	%	最大力下的塑性延伸率, F_m
A_{gt}	%	最大力下的总延伸率, F_m
A_t	%	断裂时的总延伸率
ΔL_m	毫米	最大力下的延伸
ΔL_f	毫米	断裂时的延伸
速率		
e_{Le}	s^{-1}	应变率
$\dot{e}_{Lc}$	s^{-1}	平行长度上的估计应变率
$\dot{R}$	兆帕 s^{-1}	应力率
v_c	毫米 s^{-1}	十字头分离速率
力		
F_m	N	最大力
屈服强度——规定强度——抗拉强度		

R	MPa ^b	应力
R_{eff}	兆帕	上屈服强度
R_{eL}	兆帕	下屈服强度
R_m	兆帕	抗拉强度
R_n	兆帕	规定塑性延伸强度
R_r	兆帕	规定永久变形强度
R_t	兆帕	规定总延伸强度
弹性模量——应力-延伸率曲线的斜率		
E	吉帕	^c 弹性模量
m	兆帕	试验给定时刻应力-延伸率曲线的斜率
m_E	兆帕	应力-延伸率曲线弹性部分的斜率 ^d
R_1	兆帕	较低应力值
R_2	兆帕	较高应力值
- 钢管产品标准中使用的符号。b 1MPa = 1Nmm ⁻² 。弹性模量的计算见附录 G。在确定规定强度时，不要求使用附录 G 来确定应力-延伸率曲线弹性部分的斜率。 ^d 在应力-延伸率曲线的弹性部分，斜率值不一定代表弹性模量。如果采用最佳条件 (见附录 G)，该值可能与弹性模量值非常接近。		

CAUTION — The factor 100 is necessary if percentage values are used.

注意 — 如果使用百分比值，则需要乘以 100 这个系数。

Table 1 (continued)

表 1(续)

Symbol	Unit	Designation
e_1	%	lower strain value
e_2	%	upper strain value
R^2	-	coefficient of determination
S_m	MPa	standard deviation of the slope
$S_{m(\text{rel})}$	%	relative standard deviation of the slope
符号	单位	名称
e_1	%	较低应变值
e_2	%	较高应变值
R^2	-	决定系数
S_m	兆帕(MPa)	斜率标准差

$S_{m(rel)}$	%	斜率相对标准差
--------------	---	---------

a Symbol used in steel tube product standards.

钢管产品标准中使用的一个符号。

b $1\text{ MPa} = 1\text{ N mm}^{-2}$.

^c The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

^c 弹性模量的计算在附录 G 中说明。对于规定塑性延伸强度测定时应力-延伸率曲线弹性部分斜率的测定，无需使用附录 G。

^d In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).

^d 在应力-延伸率曲线的弹性部分，斜率值不一定代表弹性模量。如果采用最佳条件(见附录 G)，该值可能与弹性模量值非常接近。

CAUTION — The factor 100 is necessary if percentage values are used.

注意 — 如果使用百分比值，则系数 100 是必需的。

5 Principle

5 原理

The test involves straining a test piece by tensile force, generally to fracture, for the determination of one or more of the mechanical properties defined in Clause 3.

试验通过对试样施加拉伸力使其变形，通常直至断裂，以测定第 3 条中定义的一种或多种力学性能。

The test shall be carried out at room temperature between 10 ° C and 35 ° C, unless otherwise specified. For laboratory environments outside the stated requirement, it is the responsibility of the testing laboratory to assess the impact on testing and/or calibration data produced with and for testing machines operated in such environments. When testing and calibration activities are performed outside the temperature limits of 10°C and 35°C, the temperature shall be recorded and reported. If significant temperature gradients are present during testing and/or calibration, measurement uncertainty may increase and out of tolerance conditions may occur.

除非另有规定，试验应在 10 ° 摄氏度至 35 ° 摄氏度的室温下进行。对于超出规定要求的实验室环境，测试实验室有责任评估其对在此类环境中运行的试验机所产生的测试和/或校准数据的影响。当测试和校准活动在 10°C 和 35°C 的温度范围之外进行时，应记录并报告温度。如果在测试和/或校准期间存在明显的温度梯度，测量不确定度可能会增加，并且可能会出现超出公差的情况。

Tests carried out under controlled conditions shall be made at a temperature of $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

在控制条件下进行的试验应在 $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ 的温度下进行。

If the determination of the modulus of elasticity is requested in the tensile test, this shall be done in accordance with Annex G.

如果在拉伸试验中要求测定弹性模量，则应按照附录 G 进行。

6 Test pieces

6 试样

6.1 Shape and dimensions

6.1 形状和尺寸

6.1.1 General

6.1.1 一般规定

The shape and dimensions of the test pieces may be constrained by the shape and dimensions of the metallic product from which the test pieces are taken.

试样的形状和尺寸可能受到取样的金属产品的形状和尺寸的限制。

The test piece is usually obtained by machining a sample from the product or a pressed blank or casting. However, products of uniform cross-section (sections, bars, wires, etc.) and also as-cast test pieces (i.e. for cast iron and non-ferrous alloys) may be tested without being machined.

试样通常通过从产品、压制坯料或铸件上加工样品获得。然而，具有均匀横截面的产品(型材、棒材、线材等)以及铸态试样(即用于铸铁和有色金属合金)可以不经加工进行测试。

The cross-section of the test pieces may be circular, square, rectangular, annular or, in special cases, some other uniform cross-section.

试样的横截面可以是圆形、方形、矩形、环形，或者在特殊情况下是其他一些均匀的横截面。

Preferred test pieces have a direct relationship between the original gauge length, L_0 , and the original cross-sectional area, S_0 , expressed by the formula $L_0 = k\sqrt{S_0}$, where k is a coefficient of proportionality, and are called proportional test pieces. The internationally adopted value for k is 5,65. The original gauge length shall be not less than 15 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with $k = 5,65$, a higher value (preferably 11,3) or a non-proportional test piece may be used.

优选的试样在原始标距长度 L_0 和原始横截面积 S_0 之间具有直接关系，由公式 $L_0 = k\sqrt{S_0}$ 表示，其中 k 是比例系数，称为比例试样。国际上采用的 k 值为 5.65。原始标距长度应不小于 15 mm。当试样的横截面积过小而无法满足 $k = 5,65$ 的这一要求时，可以使用更高的值(最好是 11.3)或非比例试样。

NOTE By using an original gauge length smaller than 20 mm, the uncertainty of the result "elongation after fracture" will be increased.

注意:使用小于 20 mm 的原始标距，“断裂后伸长率”结果的不确定度将会增加。

For non-proportional test pieces, the original gauge length, L_0 , is independent of the original cross-sectional area, S_0 .

对于非比例试样，原始标距 L_0 与原始横截面积 S_0 无关。

The dimensional tolerances of the test pieces shall be in accordance with Annexes B to E (see 6.2).

试样的尺寸公差应符合附录 B 至 E(见 6.2)。

Other test pieces such as those specified in relevant product standards or national standards may be used by agreement with the customer, e.g. ISO 3183^[1] (API 5L), ISO 11960^[2] (API 5CT), ASTM A370^[6], ASTM E8M[Z], DIN 50125[10], IACS W2[13], and JIS Z 2241[14].

经与客户协商，可使用相关产品标准或国家标准中规定的其他试样，例如 ISO 3183^[1] (API 5L)、ISO 11960^[2] (API 5CT)、ASTM A370^[6]、ASTM E8M[Z]、DIN 50125[10]、IACS W2[13]和 JIS Z 2241[14]。

6.1.2 Machined test pieces

6.1.2 加工试样

Machined test pieces shall incorporate a transition radius between the gripped ends and the parallel length if these have different dimensions. The dimensions of the transition radius are important and it is recommended that they be defined in the material specification if they are not given in the appropriate annex (see 6.2).

如果加工试样的夹持端和平行长度尺寸不同，则应在两者之间设置过渡半径。过渡半径的尺寸很重要，如果相应附录中未给出(见 6.2)，建议在材料规范中予以规定。

The gripped ends may be of any shape to suit the grips of the testing machine. The axis of the test piece shall coincide with the axis of application of the force.

夹持端可以是适合试验机夹具的任何形状。试样的轴线应与施力轴线重合。

The parallel length, L_c , or, in the case where the test piece has no transition radii, the free length between the grips, shall always be greater than the original gauge length, L_0 .

平行长度 L_c ，或者在试样没有过渡半径的情况下，夹具之间的自由长度，应始终大于原始标距 L_0 。

6.1.3 Unmachined test pieces

6.1.3 未加工试样

If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall be sufficient for gauge marks to be at a reasonable distance from the grips (see Annexes B to E).

如果试样由产品的未加工长度或未加工试棒组成，则夹具之间的自由长度应足以使标距标记与夹具保持合理距离(见附录 B 至 E)。

As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length. The dimensions of this transition radius are important and it is recommended that they be defined in the product standard. The gripped ends may be of any shape to suit the grips of the testing machine provided that they enable the centre of the test piece to coincide with the axis of application of force. The parallel length, L_c , shall always be greater than the original gauge length, L_0 .

铸态试样应在夹持端和平行长度之间设置过渡半径。该过渡半径的尺寸很重要，建议在产品标准中予以规定。夹持端可以是适合试验机夹具的任何形状，只要能使试样中心与施力轴线重合即可。平行长度 L_c 应始终大于原始标距 L_0 。

6.2 Types

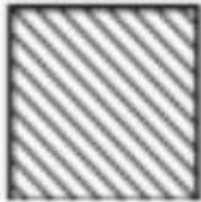
6.2 类型

The main types of test pieces are defined in Annexes B to E according to the shape and type of product, as shown in Table 2. Other types of test pieces can be specified in product standards.

根据产品的形状和类型，附录 B 至 E 中定义了主要的试样类型，如表 2 所示。其他类型的试样可在产品标准中规定。

Table 2 — Main types of test pieces according to product type

表 2 — 根据产品类型划分的主要试样类型

Type of product				Correspondi ng annex
Sheets — Plates — Flats	Wire - Bars - Sections			
				
Thickness a	Diameter or side			
$0,1 \leq a < 3$	-			B
-	< 4			C
$a \geq 3$	≥ 4			D
Tubes				E
产品类型				相应附件
薄板 - 中厚板 - 扁钢	线材 - 棒材 - 型材			

				
厚度 a	直径或边长			
$0,1 \leq a < 3$	-			B
-	< 4			C
$a \geq 3$	≥ 4			D
管材				E

6.3 Preparation of test pieces

6.3 试件制备

The test pieces shall be taken and prepared in accordance with the requirements of the relevant International Standards for the different materials (e.g. ISO 377).

应根据不同材料的相关国际标准(如 ISO 377)的要求获取并制备试件。

7 Determination of original cross-sectional area

7 原始横截面积的测定

The relevant dimensions of the test piece should be measured at sufficient cross-sections perpendicular to the longitudinal axis in the central region of the parallel length of the test piece.

应在试件平行长度中心区域内，在足够数量的垂直于纵向轴线的横截面上测量试件的相关尺寸。

A minimum of three cross-sections is recommended.

建议至少测量三个横截面。

The original cross-sectional area, S_0 , is the average cross-sectional area and shall be calculated from the measurements of the appropriate dimensions.

原始横截面积 A_0 是平均横截面积，应根据适当尺寸的测量值计算得出。

The accuracy of this calculation depends on the nature and type of the test piece. Annexes B to E describe methods for the evaluation of S_0 for different types of test pieces and contain specifications for the accuracy of measurement.

该计算的准确性取决于试件的性质和类型。附录 B 至 E 描述了不同类型试件 A_0 的评估方法，并包含测量精度的规范。

All measuring devices used for the determination of the original cross-sectional area shall be calibrated to the appropriate reference standards with traceability to a national measurement system.

用于测定原始横截面积的所有测量设备均应按照适当的参考标准进行校准，并可追溯至国家测量系统。

8 Original gauge length and extensometer gauge length

8 原始标距长度和引伸计标距长度

8.1 Choice of the original gauge length

8.1 原始标距长度的选择

For proportional test pieces, if the original gauge length is not equivalent to $5,65\sqrt{S_0}$, where S_0 is the original cross-sectional area of the parallel length, the symbol A should be supplemented by a subscript indicating the coefficient of proportionality used, e.g. $A_{11.3}$ indicates a percentage elongation of the gauge length, L_0 , according to Formula (1):

对于比例试件，如果原始标距长度不等于 $5.65\sqrt{A_0}$ (其中 A_0 是平行长度的原始横截面积)，则符号 L_0 应补充一个下标，以表明所使用的比例系数，例如 $A_{11.3}$ 表示标距长度 L_0 根据公式(1)的伸长率：

$$L_0 = 11,3\sqrt{S_0} \quad (1)$$

NOTE $5,65\sqrt{S_0} = 5\sqrt{4S_0/\pi}$.

注 A_0 。

For non-proportional test pieces (see Annex B and Annex D), the symbol A should be supplemented by a subscript indicating the original gauge length used, expressed in millimetres, e.g. $A_{80 \text{ mm}}$ indicates a percentage elongation of a gauge length, L_0 , of 80 mm.

对于非比例试件(见附录 B 和附录 D), 符号 L_0 应补充一个下标, 以表明所使用的原始标距长度, 单位为毫米, 例如 A_{50} 表示标距长度 L_0 为 50 毫米的伸长率。

8.2 Marking the original gauge length

8.2 标记原始标距长度

For the manual determination of the elongation after fracture A , each end of the original gauge length, L_0 , shall be marked by means of fine marks, scribed lines, or punch marks, but not by marks which could result in premature fracture. The original gauge length shall be marked to an accuracy of $\pm 1\%$.

对于手动测定断裂后伸长率 A_0 , 原始标距长度 L_0 的每一端均应通过细标记、划线或冲痕进行标记, 但不得使用可能导致过早断裂的标记。原始标距长度的标记精度应为 $\pm 1\%$ 。

For proportional test pieces, the calculated value of the original gauge length may be rounded to the nearest multiple of 5 mm, provided that the difference between the calculated and marked gauge length is less than 10% of L_0 .

对于比例试件, 原始标距长度的计算值可以四舍五入到最接近的 $5\sqrt{A_0}$ 的倍数, 前提是计算的标距长度与标记的标距长度之间的差值小于 1% 的 L_0 。

If the parallel length, L_c , is much greater than the original gauge length, as, for instance, with unmachined test pieces, a series of overlapping gauge lengths may be marked.

如果平行长度 L_c 远大于原始标距长度, 例如对于未加工的试件, 可标记一系列重叠的标距长度。

In some cases, it can be helpful to draw a line parallel to the longitudinal axis, along which the gauge lengths are marked.

在某些情况下, 绘制一条与纵向轴线平行的线可能会有所帮助, 标距长度沿此线标记。

8.3 Choice of the extensometer gauge length

8.3 引伸计标距长度的选择

For measurement of yield and proof strength parameters, L_e should span as much of the parallel length of the test piece as possible. Ideally, as a minimum, L_e should be greater than $0.5L_0$ but less than approximately $0.9L_c$. This should ensure that the

extensometer detects all yielding events that occur in the test piece. Further, for measurement of parameters "at" or "after reaching" maximum force, L_e should be approximately equal to L_0 .

为了测量屈服强度和规定强度参数, L_e 应尽可能覆盖试件的平行长度。理想情况下, 至少 L_e 应大于 $0.50L_0$ 但小于约 $0.9L_c$ 。这应确保引伸计检测到试件中发生的所有屈服事件。此外, 为了测量“达到”或“达到后”最大力时的参数, L_e 应约等于 L_0 。

9 Accuracy of testing apparatus

9 试验设备的精度

The force-measuring system of the testing machine shall be in accordance with ISO 7500-1, class 1, or better.

试验机的测力系统应符合 ISO 7500-1 的 1 级或更高等级。

For the determination of proof strength (plastic or total extension), the extensometer used shall be in accordance with ISO 9513, class 1 or better, in the relevant range. For other properties (with extensions greater than 5%), an ISO 9513, class 2 extensometer in the relevant range may be used.

对于规定强度(塑性延伸或总延伸)的测定, 所用引伸计在相关范围内应符合 ISO 9513 的 1 级或更高等级。对于其他性能(延伸率大于 5%), 在相关范围内可使用 ISO 9513 的 2 级引伸计。

10 Conditions of testing

10 试验条件

10.1 Setting the force zero point

10.1 设置力零点

The force-measuring system shall be set to zero after the testing loading train has been assembled, but before the test piece is actually gripped at both ends. Once the force zero point has been set, the force-measuring system shall not be changed in any way during the test.

测力系统应在试验加载装置组装完成后，但在试件两端实际夹紧之前设置为零。一旦设置了力零点，在试验过程中测力系统不得以任何方式改变。

NOTE The use of this method ensures that, on one hand, the weight of the gripping system is compensated for in the force measurement, and on the other hand, any force resulting from the clamping operation does not affect this measurement.

注 使用此方法可确保，一方面，在力测量中补偿夹紧系统的重量，另一方面，夹紧操作产生的任何力不会影响此测量。

10.2 Method of gripping

10.2 夹紧方法

The test pieces shall be gripped by suitable means, such as wedges, screwed grips, parallel jaw faces, or shouldered holders.

试件应采用合适的方式夹紧，如楔块、螺纹夹具、平行钳口面或带肩夹具。

Every endeavour should be made to ensure that test pieces are held in such a way that the force is applied as axially as possible, in order to minimize bending (more information is given in ASTM E1012 ^[8], for example). This is of particular importance when testing brittle materials or when determining proof strength (plastic extension), proof strength (total extension), or yield strength.

应尽一切努力确保试件的夹持方式使力尽可能轴向施加，以尽量减少弯曲(例如，ASTM E1012 ^[8] 中提供了更多信息)。在测试脆性材料或测定规定强度(塑性延伸)、规定强度(总延伸)或屈服强度时，这一点尤为重要。

In order to ensure the alignment of the test piece and grip arrangement, a preliminary force may be applied provided it does not exceed a value corresponding to 5% of the specified or expected yield strength. A correction of the extension should be carried out to take into account the effect of the preliminary force.

为了确保试件与夹具装置的对准，可施加一个预加载力，前提是该力不超过对应于规定或预期屈服强度 5% 的值。应进行延伸修正以考虑预加载力的影响。

10.3 Testing rates

10.3 试验速率

10.3.1 General information regarding testing rates

10.3.1 关于试验速率的一般信息

Unless otherwise agreed, the choice of method (A1, A2, or B) and test rates are at the discretion of the producer or the test laboratory assigned by the producer, provided that these meet the requirements of this document.

除非另有约定，方法(A1、A2 或 B)的选择以及试验速率由生产商或生产商指定的试验实验室自行决定，前提是这些符合本文件的要求。

NOTE 1 The difference between Method A and Method B is that the necessary testing speed of Method A is defined at the point of interest (e.g. $R_{p0.2}$), where the property has to be determined, whereas, in Method B, the necessary testing speed is set in the elastic range before the property (e.g. $R_{p0.2}$) has to be determined.

注 1:方法 A 和方法 B 的区别在于，方法 A 的必要试验速度在感兴趣的点(例如 $R_{p0.2}$)定义，在该点必须确定性能，而在方法 B 中，必要试验速度在必须确定性能(例如 $R_{p0.2}$)之前的弹性范围内设定。

Under certain conditions using Method B (e.g. for some steels a stress rate in the elastic range of approximately 30MPa/s, using a testing rig and clamping system with high stiffness and a test piece geometry according to Annex B, Table B.1, Test piece type 2), a strain rate near the range 2 of Method A may be observed.

在某些条件下使用方法 B(例如对于某些钢材，在弹性范围内应力速率约为 30MPa/s，使用具有高刚度的试验装置和夹紧系统以及符合附录 B 表 B.1 的试件几何形状，试件类型 2)，可能会观察到接近方法 A 范围 2 的应变速率。

NOTE 2 Product standards and corresponding test standards (e.g. aerospace standards) can specify test rates that are different from those contained in this document.

注 2:产品标准和相应的试验标准(例如航空航天标准)可以规定与本文件中不同的试验速率。

10.3.2 Testing rate based on strain rate (method A)

10.3.2 基于应变速率的试验速率(方法 A)

10.3.2.1 General

10.3.2.1 一般规定

Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

方法 A 旨在尽量减少在确定应变速率敏感参数时试验速率的变化，并尽量减少试验结果的测量不确定度。

Two different types of strain rate control are described in this subclause.

本条款描述了两种不同类型的应变速率控制。

- Method A1 closed loop involves the control of the strain rate itself, $\dot{\epsilon}_{L_e}$, that is based on the feedback obtained from an extensometer.
- 方法 A1 闭环控制涉及对应变速率本身 $\dot{\epsilon}_{L_e}$ 的控制，该控制基于从引伸计获得的反馈。
- Method A2 open loop involves the control of the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, which is achieved by using the crosshead separation rate calculated by multiplying the required strain rate by the parallel length [see Formula (2)].
- 方法 A2 开环控制涉及对平行长度上估计应变速率 $\dot{\epsilon}_{L_c}$ 的控制，这是通过使用将所需应变速率乘以平行长度计算得到的十字头分离速率来实现的[见公式(2)]。

NOTE A more rigorous strain rate estimation procedure for Method A2 is described in Annex E.

注:附录 E 中描述了方法 A2 更严格的应变速率估计程序。

If a material shows no discontinuous yielding and the force remains nominally constant, the strain rate, $\dot{\epsilon}_{L_e}$, and the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, are approximately equal. Differences exist if the material exhibits discontinuous or serrated yielding (e.g. some steels and AlMg alloys in the yield point extension range, or materials which show serrated yielding like the Portevin-Le Chatelier

effect) or if necking occurs. If the force is increasing, the strain rate [if the crosshead separation rate is calculated using Formula (2)] may be below the target strain rate due to the compliance of the testing machine.

如果材料没有明显屈服且力名义上保持恒定，则应变速率 $\dot{\epsilon}_{L_e}$ 和在平行长度上的估计应变速率 $\dot{\epsilon}_{L_c}$ 大致相等。如果材料表现出明显屈服或锯齿状屈服(例如在屈服点延伸范围内的一些钢材和铝镁合金，或表现出锯齿状屈服的材料，如 Portevin-Le Chatelier 效应)或发生颈缩，则会存在差异。如果力在增加，由于试验机的柔度，应变速率[如果使用公式(2)计算十字头分离速率]可能会低于目标应变速率。

The testing rate shall conform to the following requirements.

试验速率应符合以下要求。

a) Unless otherwise specified, any convenient speed of testing may be used up to a stress equivalent to half of the expected yield strength. Above this range and for the determination of R_{eH} , R_p or R_t , the specified strain rate, $\dot{\epsilon}_{L_e}$ (or for Method A2 the crosshead separation rate v_c), shall be applied. In this range, to eliminate the influence of the compliance of the tensile testing machine, the use of an extensometer measuring the extension of the test piece is necessary to have accurate control over the strain rate. For testing machines unable to control by strain rate, method A2 may be used.

a) 除非另有规定，在应力相当于预期屈服强度的一半之前，可以使用任何方便的试验速度。在此范围之上以及为了确定 R_{eH} , R_p 或 R_t ，应采用规定的应变速率 $\dot{\epsilon}_{L_e}$ (或对于方法 A2，十字头分离速率 v_c)。在此范围内，为了消除拉伸试验机柔度的影响，需要使用测量试件伸长的引伸计来精确控制应变速率。对于无法通过应变速率控制的试验机，可以使用方法 A2。

b) During discontinuous yielding, the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$ (see 3.7.2), should be applied. In this range, it is impossible to control the strain rate using the extensometer clamped on to the test piece because local yielding can occur outside the extensometer gauge length. The required estimated strain rate over the parallel length may be maintained in this range sufficiently accurately using a constant crosshead separation rate, v_c (see 3.7.3) (open loop).

b) 在明显屈服期间，应采用在平行长度上的估计应变速率 $\dot{\epsilon}_{L_c}$ (见 3.7.2)。在此范围内，由于局部屈服可能发生在引伸计标距长度之外，因此无法使用夹在试件上的引伸计来控制应变速率。使用恒定的十字头分离速率 v_c (见 3.7.3)(开环)可以在此范围内足够精确地保持所需的在平行长度上的估计应变速率。

$$v_c = L_c \dot{\epsilon}_{L_c} \quad (2)$$

where

哪里

$\dot{\epsilon}_{L_c}$ is the estimated strain rate over the parallel length;

$\dot{\epsilon}_{L_c}$ 为平行长度上的估计应变率;

L_c is the parallel length.

L_c 为平行长度。

c) In the range following R_p or R_t or end of yielding (see 3.7.2), $\dot{\epsilon}_{L_e}$ or $\dot{\epsilon}_{L_c}$ can be used. The use of $\dot{\epsilon}_{L_c}$ is recommended to avoid any control problems which may arise if necking occurs outside the extensometer gauge length.

c) 在跟随 R_p 或 R_t 之后的范围或屈服结束时(见 3.7.2), 可以使用 $\dot{\epsilon}_{L_e}$ 或 $\dot{\epsilon}_{L_c}$ 。建议使用 $\dot{\epsilon}_{L_c}$ 以避免如果在引伸计标距长度之外发生颈缩可能出现的任何控制问题。

The strain rates specified in 10.3.2.2 to 10.3.2.4 shall be maintained during the determination of the relevant material property (see also Figure 9).

在相关材料性能的测定过程中, 应保持 10.3.2.2 至 10.3.2.4 中规定的应变率(另见图 9)。

During switching to another strain rate or to another control mode, no discontinuities in the stress-strain curve should be introduced which distort the values of R_m , A_g , or A_{gt} (see Figure 10). This effect can be reduced by a suitable gradual switch between the rates.

在切换到另一个应变率或另一种控制模式时, 不应引入应力 - 应变曲线中的不连续性, 以免扭曲 R_m , A_g 或 A_{gt} 的值(见图 10)。通过在速率之间进行适当的逐渐切换, 可以减小这种影响。

The shape of the stress-strain curve in the work-hardening range can also be influenced by the strain rate. The testing rate used should be documented (see 10.3.4).

加工硬化范围内应力 - 应变曲线的形状也会受到应变率的影响。所使用的试验速率应予以记录(见 10.3.4)。

10.3.2.2 Strain rate for the determination of the upper yield strength, R_{eH} , or proof strength properties, R_p and R_t

10.3.2.2 测定上屈服强度 R_{eH} 、规定塑性延伸强度性能 R_p 和 R_t 时的应变率

The strain rate, $\dot{\epsilon}_{Le}$, shall be kept as constant as possible up to and including the determination of R_{eH} or R_p or R_t . During the determination of these material properties, the strain rate, $\dot{\epsilon}_{Le}$, shall be in one of the two following specified ranges (see also Figure 9).

应变率 $\dot{\epsilon}_{Le}$ 在测定 R_{eH} 或 R_p 或 R_t 之前及过程中应尽可能保持恒定。在测定这些材料性能期间，应变率 $\dot{\epsilon}_{Le}$ 应处于以下两个规定范围之一(另见图 9)。

Range 1: $\dot{\epsilon}_{Le} = 0,00007 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$.

范围 1: $\dot{\epsilon}_{Le} = 0,00007 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ 。

Range 2: $\dot{\epsilon}_{Le} = 0,000 \text{ } 25 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$ (recommended, unless otherwise specified).

范围 2: $\dot{\epsilon}_{Le} = 0,000 \text{ } 25 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ (推荐, 除非另有规定)。

If the testing machine is not able to control the strain rate directly, Method A2 shall be used.

如果试验机不能直接控制应变率，则应使用方法 A2。

10.3.2.3 Strain rate for the determination of the lower yield strength, R_{eL} , and percentage yield point extension, A_e

10.3.2.3 测定下屈服强度 R_{eL} 和屈服点伸长率 A_e 时的应变率

Following the detection of the upper yield strength (see A.3.2), the estimated strain rate over the parallel length, $\dot{\epsilon}_{Lc}$, shall be maintained in one of the following two specified ranges (see Figure 9) until discontinuous yielding has ended.

在上屈服强度检测之后(见 A.3.2)，平行长度上的估计应变率 $\dot{\epsilon}_{Lc}$ 应保持在以下两个规定范围之一(见图 9)，直到连续屈服结束。

Range 2: $\dot{\epsilon}_{L_c} = 0,000025 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$ (recommended, when R_{eL} is determined). Range 3: $\dot{\epsilon}_{L_c} = 0,002 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$.

范围 2: $\dot{\epsilon}_{L_c} = 0,000025 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ (在测定 R_{eL} 时推荐)。范围 3: $\dot{\epsilon}_{L_c} = 0,002 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ 。

10.3.2.4 Strain rate for the determination of the tensile strength, R_m , percentage elongation after fracture, A , percentage total extension at the maximum force, $\tilde{A}_{gt}$, percentage plastic extension at maximum force, A_g , and percentage reduction area, Z

10.3.2.4 测定抗拉强度 R_m 、断后伸长率 A 、最大力总伸长率 $\tilde{A}_{gt}$ 、最大力塑性伸长率 A_g 和断面收缩率 Z 时的应变率

After determination of the required yield/proof strength properties, the estimated strain rate over the parallel length, $\dot{\epsilon}_{L_c}$, shall be changed to one of the following specified ranges (see Figure 9).

在确定所需的屈服/规定强度性能后，平行长度上的估计应变率 $\dot{\epsilon}_{L_c}$ 应改为以下规定范围之一(见图 9)。

Range 2: $\dot{\epsilon}_{L_c} = 0,00025 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$.

范围 2: $\dot{\epsilon}_{L_c} = 0,00025 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ 。

Range 3: $\dot{\epsilon}_{L_c} = 0,002 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$.

范围 3: $\dot{\epsilon}_{L_c} = 0,002 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ 。

Range 4: $\dot{\epsilon}_{L_c} = 0,0067 \text{ s}^{-1}$, with a relative tolerance of $\pm 20\%$ ($0,4 \text{ min}^{-1}$, with a relative tolerance of $\pm 20\%$) (recommended, unless otherwise specified).

范围 4: $\dot{\epsilon}_{L_c} = 0,0067 \text{ s}^{-1}$, 相对公差为 $\pm 20\%$ ($0,4 \text{ min}^{-1}$, 相对公差为 $\pm 20\%$) (推荐, 除非另有规定)。

If the purpose of the tensile test is only to determine the tensile strength, then an estimated strain rate over the parallel length of the test piece according to range 3 or 4 may be applied throughout the entire test.

如果拉伸试验的目的仅是确定抗拉强度，则在整个试验过程中可采用根据范围 3 或 4 确定的试件平行长度上的估计应变率。

10.3.3 Testing rate based on stress rate (method B)

10.3.3 基于应力速率的试验速率(方法 B)

10.3.3.1 General

10.3.3.1 一般规定

The testing rates shall conform to the following requirements depending on the nature of the material. Unless otherwise specified, any convenient speed of testing may be used up to a stress equivalent to half of the specified yield strength. The testing rates above this point are specified below.

试验速率应根据材料的性质符合以下要求。除非另有规定，在达到规定屈服强度一半的应力之前，可使用任何方便的试验速度。超过此点的试验速率在以下规定。

NOTE It is not the intent of Method B to maintain constant stress rate or to control stress rate with closed loop force control while determining yield properties, but only to set the crosshead speed to achieve the target stress rate in the elastic region (see Table 3). When a specimen being tested begins to yield, the stressing rate decreases and can even become negative in the case of a specimen with discontinuous yielding. The attempt to maintain a constant stressing rate through the yielding process requires the testing machine to operate at extremely high speeds and, in most cases, this is neither practical nor desirable.

注:方法 B 的目的不是在确定屈服性能时保持恒定的应力速率或通过闭环力控制来控制应力速率,而仅是设置十字头速度以在弹性区域达到目标应力速率(见表 3)。当被测试的试样开始屈服时,应力速率会降低,对于具有不连续屈服的试样,应力速率甚至可能变为负值。试图在整个屈服过程中保持恒定的应力速率要求试验机以极高的速度运行,并且在大多数情况下,这既不实际也不可取。

10.3.3.2 Yield and proof strengths

10.3.3.2 屈服强度和规定强度

10.3.3.2.1 Upper yield strength, R_{eH}

10.3.3.2.1 上屈服强度， R_{eH}

The rate of separation of the crossheads of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3.

试验机十字头的分离速率应尽可能保持恒定，并在表 3 中对应力速率的限制范围内。

NOTE For information, typical materials having a modulus of elasticity smaller than 150 000 MPa include magnesium, aluminium alloys, brass, and titanium. Typical materials with a modulus of elasticity greater than 150 000 MPa include wrought iron, steel, tungsten, and nickel-based alloys.

注:作为参考，弹性模量小于 150000MPa 的典型材料包括镁、铝合金、黄铜和钛。弹性模量大于 150000MPa 的典型材料包括熟铁、钢、钨和镍基合金。

Table 3 — Stress rate

表 3——应力速率

Modulus of elasticity of the material	Stress rate R MPa s ⁻¹	
E		
MPa		
	min.	max .
<150 000	2	20
≥150 000	6	60
材料的弹性模量	应力速率 R 兆帕 s ⁻¹	
E		
兆帕		
	分钟	max .
<150 000	2	20
≥150000	6	60

10.3.3.2.2 Lower yield strength, R_{eL}

10.3.3.2.2 较低的屈服强度, R_{eL}

If only the lower yield strength is being determined, the strain rate during yield of the parallel length of the test piece shall be between $0,000\ 25\ s^{-1}$ and $0,002\ 5\ s^{-1}$. The strain rate within the parallel length shall be kept as constant as possible. If this rate cannot be regulated directly, it shall be fixed by regulating the stress rate just before yield begins, the controls of the machine not being further adjusted until completion of yield.

如果仅测定下屈服强度, 则试验件平行长度段屈服期间的应变速率应在 $0,000\ 25\ s^{-1}$ 和 $0,002\ 5\ s^{-1}$ 之间。平行长度段内的应变速率应尽可能保持恒定。如果该速率无法直接调节, 则应通过调节屈服开始前的应力速率来确定, 在屈服完成之前不再进一步调整试验机的控制装置。

In no case shall the stress rate in the elastic range exceed the maximum rates given in Table 3.

在任何情况下, 弹性范围内的应力速率均不得超过表 3 中给出的最大速率。

10.3.3.2.3 Upper and lower yield strengths, R_{eH} and R_{eL}

10.3.3.2.3 上屈服强度和下屈服强度, R_{eH} 与 R_{eL}

If both upper and lower yield strengths are determined during the same test, the conditions for determining the lower yield strength shall be complied with (see 10.3.3.2.2).

如果在同一次试验中测定了上屈服强度和下屈服强度, 则应符合测定下屈服强度的条件(见 10.3.3.2.2)。

10.3.3.2.4 Proof strength (plastic extension) and proof strength (total extension), R_p and R_t

10.3.3.2.4 规定强度(塑性延伸)和规定强度(总延伸), R_p 和 R_t

The crosshead separation rate of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3 for the elastic range. This crosshead separation rate shall be maintained up to the proof strength

(plastic extension or total extension). In any case, the strain rate shall not exceed $0,0025 \text{ s}^{-1}$.

机器的十字头分离速率应尽可能保持恒定，并在弹性范围内对应于表 3 中应力速率的限值内。该十字头分离速率应保持到规定强度(塑性延伸或总延伸)。在任何情况下，应变率均不得超过 $0,0025 \text{ s}^{-1}$ 。

10.3.3.2.5 Rate of separation

10.3.3.2.5 分离速率

If the testing machine is not capable of measuring or controlling the strain rate, a crosshead separation rate equivalent to the stress rate given in Table 3 shall be used until completion of yield.

如果试验机无法测量或控制应变率，则应采用与表 3 中给出的应力率等效的十字头分离率，直至屈服完成。

10.3.3.3 Tensile strength, R_m , percentage elongation after fracture, A , percentage total extension at the maximum force, A_{gt} , percentage plastic extension at maximum force, A_g , and percentage reduction area, Z

10.3.3.3 拉伸强度(R_m)、断裂后伸长率(A)、最大力下总伸长率(A_{gt})、最大力下塑性伸长率(A_g)以及断面收缩率(Z)

After determination of the required yield/proof strength properties, the test rate may be increased to a strain rate (or equivalent crosshead separation rate) no greater than $0,008 \text{ s}^{-1}$.

在确定所需的屈服/比例极限强度性能后，试验速率可提高至不大于 $0,008 \text{ s}^{-1}$ 的应变速率(或等效的十字头分离速率)。

If only the tensile strength of the material is to be measured, a single strain rate can be used throughout the test which shall not exceed $0,008 \text{ s}^{-1}$.

如果仅需测量材料的抗拉强度，则在整个试验过程中可采用单一应变率，该应变率不得超过 $0,008 \text{ s}^{-1}$ 。

10.3.4 Report of the chosen testing conditions

10.3.4 所选测试条件的报告

In order to report the test control mode and testing rates in an abridged form, the following system of abbreviation can be used:

为了以简化形式报告测试控制模式和测试速率，可以使用以下缩写系统：

ISO 6892-1 Annn, or ISO 6892-1 Bn

ISO 6892-1 Annn，或 ISO 6892-1 Bn

where "A" defines the use of method A (strain rate based), and "B" the use of method B (stress rate based). The symbols "nnn" are a series of up to 3 characters that refer to the rates used during each phase of the test, as defined in Figure 9, and "n" may be added to indicate the stress rate (in MPa s^{-1}) selected during elastic loading.

其中，“A”表示方法 A(基于应变率)的使用，“B”表示方法 B(基于应力率)的使用。符号“nnn”是一系列最多由 3 个字符组成的字符，用于指代测试各阶段所使用的速率，如图 9 所定义，并且可以添加“n”来表示在弹性加载期间选择的应力率(单位为 MPa s^{-1})。

EXAMPLE 1 ISO 6892-1:2019 A224 defines a test based on strain rate, using ranges 2, 2 and 4.

示例 1 ISO 6892-1:2019 A224 定义了一种基于应变率的试验，使用的范围为 2、2 和 4。

EXAMPLE 2 ISO 6892-1:2019 B30 defines a test based on stress rate, performed at a nominal stress rate of 30MPa s^{-1} .

示例 2 ISO 6892-1:2019 B30 定义了一种基于应力率的试验，试验在名义应力率为 30MPa s^{-1} 下进行。

EXAMPLE 3 ISO 6892-1:2019 B defines a test based on stress rate, performed at a nominal stress rate according to Table 3.

示例 3 ISO 6892-1:2019 B 定义了一种基于应力率的试验，试验在根据表 3 的名义应力率下进行。

11 Determination of the upper yield strength

11 上屈服强度的测定

R_{eH} may be determined from the force-extension curve or peak load indicator and is defined as the maximum value of stress prior to the first decrease in force. The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 2).

R_{eH} 可从力-伸长曲线或峰值载荷指示器确定，定义为力首次下降之前的最大应力值。该值通过将此力除以试件的原始横截面积 S_0 来计算(见图 2)。

12 Determination of the lower yield strength

12 下屈服强度的测定

R_{eL} is determined from the force-extension curve and is defined as the lowest value of stress during plastic yielding, ignoring any initial transient effects. The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 2).

R_{eL} 从力-伸长曲线确定，定义为塑性屈服期间的最低应力值，忽略任何初始瞬态效应。该值通过将此力除以试件的原始横截面积 S_0 来计算(见图 2)。

In case of materials having yield phenomena and when A_e is not to be determined: for productivity of testing, R_{eL} may be reported as the lowest stress within the first 0,25% strain after R_{eH} , not taking into account any initial transient effect. After determining R_{eL} by this procedure, the test rate may be increased as per 10.3.2.4 or 10.3.3.3. Use of this shorter procedure should be recorded on the test report.

对于有屈服现象的材料且当不测定 A_e 时:为了提高试验效率, R_{eL} 可报告为 R_{eH} 之后第一个 0,25% 应变内的最低应力, 不考虑任何初始瞬态效应。通过此程序确定 R_{eL} 后, 试验速率可按照 10.3.2.4 或 10.3.3.3 增加。使用此较短程序应记录在试验报告中。

13 Determination of proof strength, plastic extension

13 规定塑性延伸强度的测定

13.1 R_p is determined from the force-extension curve by drawing a line parallel to the linear portion of the curve and at a distance from it equivalent to the prescribed

plastic percentage extension, e.g. 0,2% . The point at which this line intersects the curve gives the force corresponding to the desired proof strength plastic extension. The latter is obtained by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 3).

13.1 R_p 通过绘制一条与曲线线性部分平行且与它的距离等于规定塑性延伸百分比 (例如 0,2%) 的线, 从力-伸长曲线确定。这条线与曲线的交点给出对应于所需规定塑性延伸强度的力。后者通过将此力除以试件的原始横截面积 S_0 获得 (见图 3)。

If the straight portion of the force-extension curve is not clearly defined, thereby preventing drawing the parallel line with sufficient precision, the following procedure is recommended (see Figure 6).

如果力-伸长曲线的直线部分未明确界定, 从而无法以足够精度绘制平行线, 则建议采用以下程序 (见图 6)。

When the presumed proof strength has been exceeded, the force is reduced to a value equal to about 10% of the force obtained. The force is then increased again until it exceeds the value obtained originally. To determine the desired proof strength, a line is drawn through the hysteresis loop. A line is then drawn parallel to this line, at a distance from the corrected origin of the curve, measured along the abscissa, equal to the prescribed plastic percentage extension. The intersection of this parallel line and the force-extension curve gives the force corresponding to the proof strength. The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 6).

当假定的规定塑性延伸强度被超过后, 将力减小到等于所获得力的约 10% 的值。然后再次增加力, 直到超过最初获得的值。为了确定所需的规定塑性延伸强度, 通过滞后回线绘制一条线。然后绘制一条与这条线平行的线, 从曲线的校正原点沿横坐标测量的距离等于规定塑性延伸百分比。这条平行线与力-伸长曲线的交点给出对应于规定塑性延伸强度的力。该值通过将此力除以试件的原始横截面积 S_0 计算 (见图 6)。

NOTE Several methods can be used to define the corrected origin of the force-extension curve. One of these is to construct a line parallel to that determined by the hysteresis loop so that it is tangential to the force-extension curve. The point where this line crosses the abscissa is the corrected origin of the force-extension curve (see Figure 6).

注 可使用几种方法来定义力-伸长曲线的校正原点。其中一种方法是构建一条与由滞后回线确定的线平行的线, 使其与力-伸长曲线相切。这条线与横坐标的交点是力-伸长曲线的校正原点 (见图 6)。

Care should be taken to ensure that the hysteresis is performed after the final proof strength has passed, but at as low an extension as possible, as performing it at excessive extensions will have an adverse effect on the slope obtained.

应注意确保在最终规定塑性延伸强度过后进行滞后回线操作，但延伸尽可能小，因为在过大延伸下进行会对所获得的斜率产生不利影响。

If not specified in product standards or agreed by the customer, it is inappropriate to determine proof strength during and after discontinuous yielding.

如果产品标准中未规定或未得到客户同意，在不连续屈服期间及之后确定规定塑性延伸强度是不合适的。

13.2 The property may be obtained without plotting the force-extension curve by using automatic devices (microprocessor, etc.) (see Annex A).

13.2 可使用自动装置(微处理器等)(见附录 A)在不绘制力-伸长曲线的情况下获得该性能。

NOTE Another available method is described in GB/T 228[12].

注:GB/T 228[12]中描述了另一种可用方法。

14 Determination of proof strength, total extension

14 规定强度、总延伸率的测定

14.1 R_t is determined on the force-extension curve, taking 10.2 into consideration, by drawing a line parallel to the ordinate axis (force axis) and at a distance from this equivalent to the prescribed total percentage extension. The point at which this line intersects the curve gives the force corresponding to the desired proof strength. The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0 (see Figure 4).

14.1 在力-延伸曲线上确定 R_t ，考虑 10.2，通过绘制一条与纵坐标轴(力轴)平行且与该轴距离等于规定总延伸率百分比的线。该线与曲线相交的点给出对应于所需规定强度的力。该值通过将此力除以试件的原始横截面积 S_0 来计算(见图 4)。

14.2 The property may be obtained without plotting the force-extension curve by using automatic devices (see Annex A).

14.2 可使用自动装置(见附录 A)在不绘制力-延伸曲线的情况下获得该性能。

15 Method of verification of permanent set strength

15 永久变形强度验证方法

The test piece is subjected to a force corresponding to the specified stress for 10 s to 12 s. This force is obtained by multiplying the specified stress by the original cross-sectional area of the test piece, S_0 . After removing the force, it is then confirmed that the permanent set extension or elongation is not more than the percentage specified for the original gauge length; see Figure 5.

对试件施加对应于规定应力的力，持续时间为 10 s 至 12 s。此力通过将规定应力乘以试件的原始横截面积 S_0 获得。去除力后，然后确认永久变形延伸率或伸长率不超过原始标距规定的百分比；见图 5。

NOTE This is a pass/fail test, which is not normally performed as a part of the standard tensile test. The stress applied to the test piece and the permissible permanent set extension or elongation are specified either by the product specification or the requester of the test. Example: Reporting " $R_{r0.5} = 750\text{MPa}$ Pass" indicates that a stress of 750 MPa was applied to the test piece and the resulting permanent set was less than or equal to 0,5 %.

注:这是一项通过/不通过测试，通常不作为标准拉伸试验的一部分进行。施加到试件上的应力以及允许的永久变形延伸率或伸长率由产品规范或试验请求者规定。示例:报告“ $R_{r0.5} = 750\text{MPa}$ 通过”表示对试件施加了 750 MPa 的应力，且产生的永久变形小于或等于 0.5%。

16 Determination of the percentage yield point extension

16 屈服点延伸率的测定

For materials that exhibit discontinuous yielding, A_e is determined from the force-extension curve by subtracting the extension at R_{eH} from the extension at the start of uniform work-hardening. The extension at the start of uniform work-hardening is defined by the intersection of a horizontal line through the last local minimum point, or a regression line through the range of yielding, prior to uniform work-hardening and a line corresponding to the highest slope of the curve occurring at the start of uniform work-hardening (see Figure 7). It is expressed as a percentage of the extensometer gauge length, L_e .

对于呈现不连续屈服的材料，通过从均匀加工硬化开始时的延伸率中减去 R_{eH} 处的延伸率，从力-延伸曲线上确定 A_e 。均匀加工硬化开始时的延伸率由通过最后一个局部最低点的水平线或通过屈服范围的回归线与对应于均匀加工硬化开始时曲线最高斜率的线的交点定义(见图 7)。它以引伸计标距 L_e 的百分比表示。

The method used [see Figure 7 a) or b)] should be documented in the test report.

所使用的方法[见图 7 a)或 b)]应在试验报告中记录。

17 Determination of the percentage plastic extension at maximum force

17 最大力下塑性延伸率的测定

The method consists of determining the extension at maximum force on the force-extension curve obtained with an extensometer and subtracting the elastic strain.

该方法包括确定用引伸计获得的力-延伸曲线上最大力时的延伸率，并减去弹性应变。

Calculate the percentage plastic extension at maximum force, A_g , from Formula (3):

根据公式(3)计算最大力下的塑性延伸率 A_g :

$$A_g = \left(\frac{\Delta L_m}{L_e} - \frac{R_m}{m_E} \right) \cdot 100 \quad (3)$$

where

式中

ΔL_m is the extension at maximum force;

L_e is the extensometer gauge length;

R_m is the tensile strength;

E is the slope of the elastic part of the stress-percentage extension curve.

E 是应力-延伸率百分比曲线弹性部分的斜率。

NOTE For materials which exhibit a plateau at maximum force, the percentage plastic extension at maximum force is the extension at the mid-point of the plateau (see Figure 1).

注:对于在最大力下呈现平台的材料，最大力下的塑性延伸率是平台中点处的延伸率(见图 1)。

18 Determination of the percentage total extension at maximum force

18 最大力下总伸长率的测定

The method consists of determining the extension at maximum force on the force-extension curve obtained with an extensometer.

该方法包括确定用引伸计获得的力 - 伸长曲线上的最大力时的伸长量。

Calculate the percentage total extension at maximum force, A_{gt} , from Formula (4):

根据公式(4)计算最大力下的总伸长率 A_{gt} :

$$A_{gt} = \frac{\Delta L_m}{L_e} \cdot 100 \quad (4)$$

where

其中

ΔL_m is the extension at maximum force;

ΔL_m 是最大力时的伸长量;

L_e is the extensometer gauge length.

L_e 是引伸计标距长度。

NOTE For materials which exhibit a plateau at maximum force, the percentage total extension at maximum force is the extension at the mid-point of the plateau (see Figure 1).

注:对于在最大力时呈现平台的材料,最大力下的总伸长率是平台中点处的伸长量(见图 1)。

19 Determination of the percentage total extension at fracture

19 断裂时总伸长率测定

The method consists of determining the extension at fracture on the force-extension curve obtained with an extensometer.

该方法包括确定用引伸计获得的力 - 伸长曲线上的断裂伸长量。

Calculate the percentage total elongation at fracture, A_t , from Formula (5):

根据公式(5)计算断裂时的总伸长率 A_t :

$$A_t = \frac{\Delta L_f}{L_e} \cdot 100 \quad (5)$$

where

其中

ΔL_f is the extension at fracture;

ΔL_f 是断裂时的伸长量;

L_e is the extensometer gauge length.

L_e 是引伸计标距长度。

20 Determination of percentage elongation after fracture

20 断裂后伸长率的测定

20.1 Percentage elongation after fracture shall be determined in accordance with the definition given in 3.4.2.

20.1 断裂后伸长率应按照 3.4.2 给出的定义进行测定。

For this purpose, the broken pieces of the test piece shall be carefully fitted back together so that their axes lie in a straight line.

为此，应小心地将试验片断口对合在一起，使它们的轴线位于一条直线上。

Special precautions shall be taken to ensure proper contact between the broken parts of the test piece when measuring the final gauge length. This is particularly important for test pieces of small cross-section and test pieces having low elongation values.

测量最终标距长度时，应采取特殊预防措施，以确保试件断裂部分之间的正确接触。这对于小横截面试件和伸长率值较低的试件尤为重要。

Calculate the percentage elongation after fracture, A , from Formula (6):

根据公式(6)计算断后伸长率， A :

$$A = \frac{L_u - L_o}{L_o} \cdot 100 \quad (6)$$

where

式中

L_u is the final gauge length after fracture;

L_u 为断后的最终标距长度；

L_o is the original gauge length.

Elongation after fracture, $L_u - L_o$, shall be determined to the nearest 0,25 mm or better using a measuring device with sufficient resolution.

断后伸长率, $L_u - L_o$, 应使用具有足够分辨率的测量装置, 精确到最接近的 0,25 mm 或更高精度。

If the specified minimum percentage elongation is less than 5% , it is recommended that special precautions be taken (see Annex H). The result of this determination is valid only if the distance between the fracture and the nearest gauge mark is not less than $L_o/3$. However, the percentage elongation after fracture can be regarded as valid, irrespective of the position of the fracture, if the percentage elongation after fracture is equal to or greater than the specified value. To avoid having to reject test pieces where the distance between the fracture and the next gauge mark is less than $L_o/3$, the method described in Annex I may be used by agreement.

如果规定的最小伸长率百分比小于 5% , 建议采取特殊预防措施(见附录 H)。只有当断裂处与最近标距标记之间的距离不小于 $L_o/3$ 时, 该测定结果才有效。然而, 如果断后伸长率等于或大于规定值, 则无论断裂位置如何, 断后伸长率百分比均可视为有效。为避免拒收断裂处与下一个标距标记之间的距离小于 $L_o/3$ 的试件, 可经协议采用附录 I 中所述的方法。

20.2 When extension at fracture is measured using an extensometer, it is not necessary to mark the gauge lengths. The elongation is measured as the total extension at fracture, and it is therefore necessary to deduct the elastic extension in order to obtain percentage elongation after fracture. To obtain comparable values with the manual method, additional adjustments can be applied (e.g. high enough dynamic and frequency bandwidth of the extensometer) (see A.2.2).

20.2 使用引伸计测量断裂伸长时, 无需对标距长度进行标记。伸长量作为断裂时的总伸长量进行测量, 因此为了获得断后伸长率, 必须扣除弹性伸长量。为了获得与手动方法可比的值, 可以进行额外的调整(例如, 引伸计具有足够高的动态和频率带宽)(见 A.2.2)。

The result of this determination is valid only if fracture and localized extension (necking) occur within the extensometer gauge length, L_e . The percentage elongation after fracture can be regarded as valid regardless of the position of the fracture cross-section if the percentage elongation after fracture is equal to or greater than the specified value. If the product standard specifies the determination of percentage elongation after fracture for a given gauge length, the extensometer gauge length should be equal to this length.

只有当断裂和局部伸长(颈缩)发生在引伸计标距长度 L_e 内时, 该测定结果才有效。如果断后伸长率等于或大于规定值, 则无论断裂横截面的位置如何, 断后伸长率百分比均可视为有效。如果产品标准规定了给定标距长度的断后伸长率的测定, 则引伸计标距长度应等于该长度。

20.3 If elongation is measured over a given fixed length, it can be converted to proportional gauge length, using conversion formulae or tables as agreed before the commencement of testing (e.g. as in ISO 2566-1 and ISO 2566-2).

20.3 如果在给定的固定长度上测量伸长率, 可以使用测试开始前商定的换算公式或表格将其换算为比例标距长度(例如, 如 ISO 2566-1 和 ISO 2566-2 中所述)。

NOTE Comparisons of percentage elongation are possible only when the gauge length or extensometer gauge length, the shape, and cross-sectional area are the same or when the coefficient of proportionality, k , is the same.

注 只有当标距长度或引伸计标距长度、形状和横截面积相同, 或者比例系数 k 相同时, 才能进行伸长率百分比的比较。

21 Determination of percentage reduction of area

21 断面收缩率的测定

Percentage reduction of area shall be determined in accordance with the definition given in 3.8.

断面收缩率应根据 3.8 中给出的定义进行测定。

If necessary, the broken pieces of the test piece shall be carefully fitted back together so that their axes lie in a straight line.

如有必要, 应小心地将试件的断片重新拼合在一起, 使其轴线位于一条直线上。

For round test pieces, the measurements at the minimum reduced section should be made in 2 planes at 90° to each other and the average used for the calculation of Z .

对于圆形试件, 应在相互成 90° 的两个平面上测量最小缩颈处的尺寸, 并取平均值用于计算 Z 。

Care should be taken to ensure that the fracture surfaces are not displaced when making the readings.

读数时应注意确保断口表面不发生位移。

Calculate the percentage reduction of area, Z , from Formula (7):

根据公式(7)计算断面收缩率, Z :

$$Z = \frac{S_o - S_u}{S_o} \cdot 100 \quad (7)$$

where

哪里

S_o is the original cross-sectional area of the parallel length;

S_o 是平行长度的原始横截面积;

S_u is the minimum cross-sectional area after fracture.

S_u 是断裂后的最小横截面积。

It is recommended to measure S_u to an accuracy of $\pm 2\%$ (see Figure 13).

建议测量 S_u 的精度达到 $\pm 2\%$ (见图 13)。

Measuring S_u with an accuracy of $\pm 2\%$ on small diameter round test pieces, or test pieces with other cross-sectional geometries, may not be possible.

对于小直径圆形试件或其他横截面几何形状的试件，可能无法将 S_u 测量到 $\pm 2\%$ 的精度。

22 Test report

22 试验报告

The test report shall contain at least the following information, unless otherwise agreed by the parties concerned:

试验报告应至少包含以下信息，除非相关各方另有约定:

a) reference to this document, extended with the test condition information specified in 10.3.4, e.g. ISO 6892-1:2019 A224;

a) 本文件的引用，并扩展 10.3.4 中规定的试验条件信息，例如 ISO 6892-1:2019 A224;

b) identification of the test piece;

b) 试件的标识;

c) specified material, if known;

c) 已知的规定材料;

d) type of test piece;

d) 试件类型;

e) location and direction of sampling of test pieces, if known;

e) 已知的试件取样位置 and 方向;

f) testing control mode(s) and testing rate(s) or testing rate range(s) (see 10.3.1) if different from the recommended methods and values given in 10.3.2 and 10.3.3;

f) 与 10.3.2 和 10.3.3 中给出的推荐方法和值不同时的试验控制模式和试验速率或试验速率范围(见 10.3.1);

g) test results:

g) 试验结果:

- results should be rounded (according to ISO 80000-1) to the following precisions or better, if not otherwise specified in product standards: strength values, in megapascals, to the nearest whole number;
- 结果应(根据 ISO 80000-1)四舍五入到以下精度或更高精度, 除非产品标准另有规定:强度值, 以兆帕为单位, 精确到最接近的整数;
- percentage yield point extension values, A_e , to the nearest 0,1% ;
- 屈服点伸长率百分比值 A_e , 精确到最接近的 0,1% ;
- all other percentage extension and elongation values to the nearest 0,5 %;
- 所有其他百分比延伸率和伸长率值精确到最接近的 0.5%;
- percentage reduction of area, Z , to the nearest 1% .
- 断面收缩率, Z , 精确到最接近的 1% 。

23 Measurement uncertainty

23 测量不确定度

23.1 General

23.1 一般规定

Measurement uncertainty analysis is useful for identifying major sources of inconsistencies of measured results.

测量不确定度分析有助于识别测量结果不一致的主要来源。

Product standards and material property databases based on this document and earlier editions of ISO 6892 have an inherent contribution from measurement uncertainty. It is therefore inappropriate to apply further adjustments for measurement uncertainty and thereby risk failing product which is compliant. For this reason, the estimates of uncertainty derived by following this procedure are for information only.

基于本文件以及 ISO 6892 早期版本的产品标准和材料性能数据库中，测量不确定度有其内在影响。因此，对测量不确定度进行进一步调整是不合适的，否则可能会使合格产品被判为不合格。因此，按照本程序得出的不确定度估计值仅供参考。

23.2 Test conditions

23.2 试验条件

The test conditions and limits defined in this document shall not be adjusted to take account of uncertainties of measurement.

本文件中规定的试验条件和限值不得因考虑测量不确定度而进行调整。

23.3 Test results

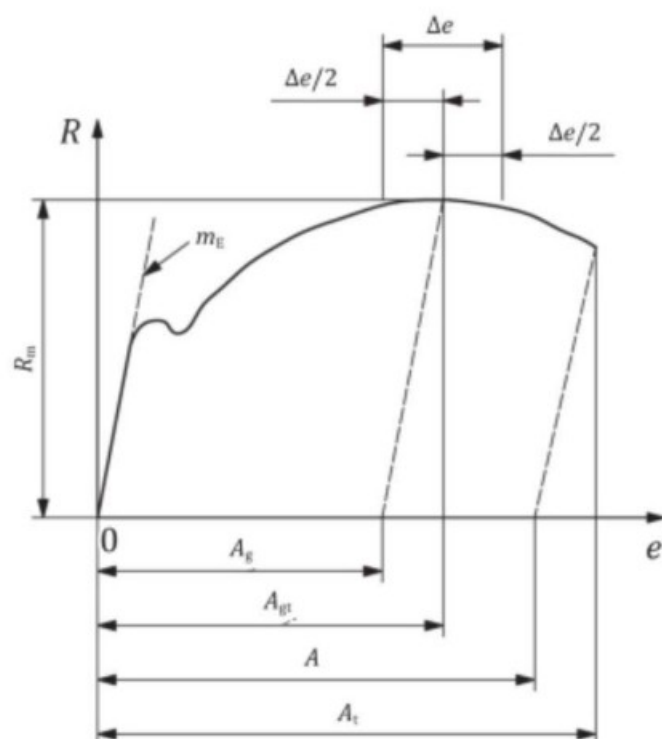
23.3 试验结果

The estimated measurement uncertainties shall not be combined with measured results to assess conformance to product specifications.

估计的测量不确定度不得与测量结果合并以评估是否符合产品规范。

For consideration of uncertainty, see Annexes K and L, which provide guidance for the determination of uncertainty related to metrological parameters and values obtained from the interlaboratory tests on a group of steels and aluminium alloys.

关于不确定度的考虑，见附录 K 和 L，它们为与计量参数以及从一组钢和铝合金的实验室间试验获得的值相关的不确定度的确定提供了指导。



Key

关键词

A percentage elongation after fracture [determined from the extensometer signal or directly from the test piece (see 20.1)]

A 断后伸长率[由引伸计信号或直接从试样确定(见 20.1)]

A_g percentage plastic extension at maximum force

A_g 最大力下的塑性延伸率

A_{gt} percentage total extension at maximum force

A_{gt} 最大力下的总延伸率

A_t percentage total extension at fracture

A_t 断后总延伸率

e percentage extension

伸长百分比

m_E slope of the elastic part of the stress-percentage extension curve

m_E 应力 - 伸长百分比曲线弹性部分的斜率

R stress

R 应力

R_m tensile strength

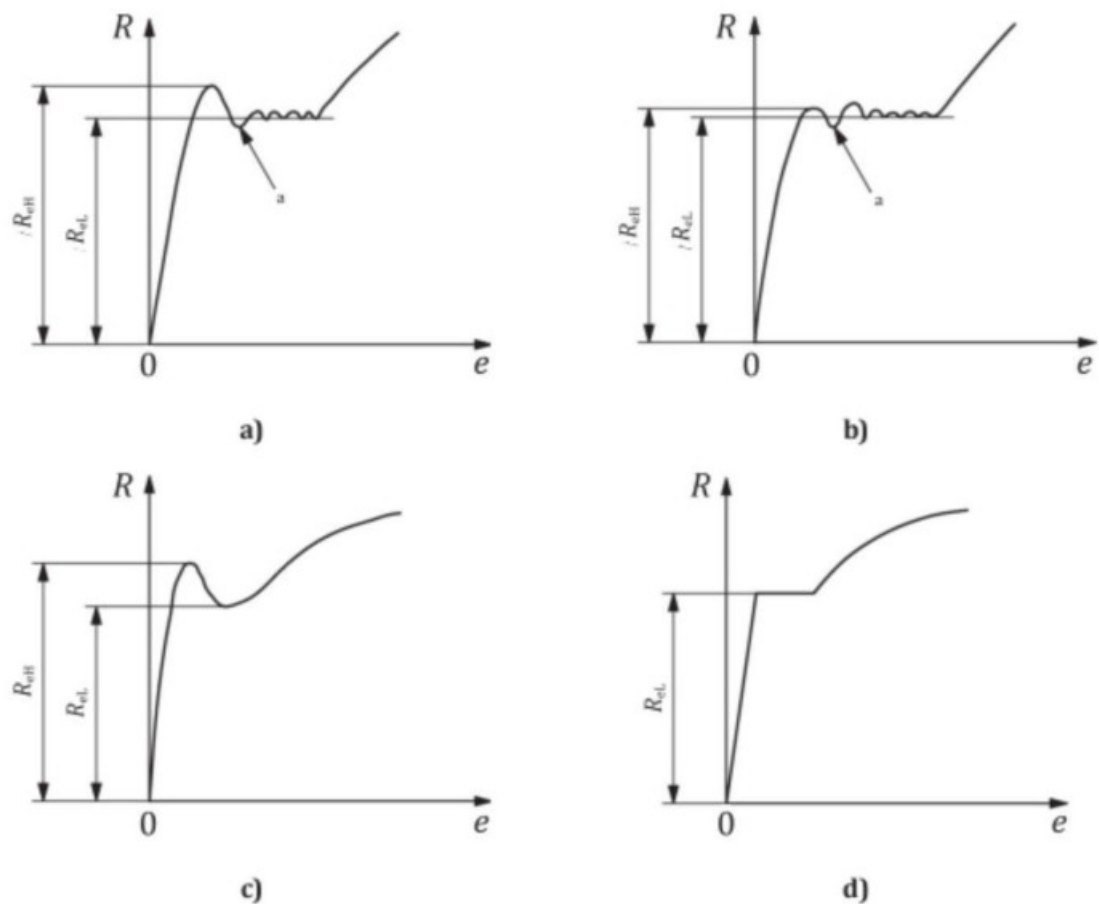
R_m 抗拉强度

Δe plateau extent (for determination of A_g , see Clause 17, for determination of A_{gtr} , see Clause 18)

Δe 平台长度(对于 A_g 的测定, 见第 17 条; 对于 A_{gtr} 的测定, 见第 18 条)

Figure 1 - Definitions of extension

图 1 - 伸长的定义



Key

关键

e percentage extension

伸长百分比

R stress

R 应力

R_{eH} upper yield strength

R_{eH} 上屈服强度

R_{eL} lower yield strength

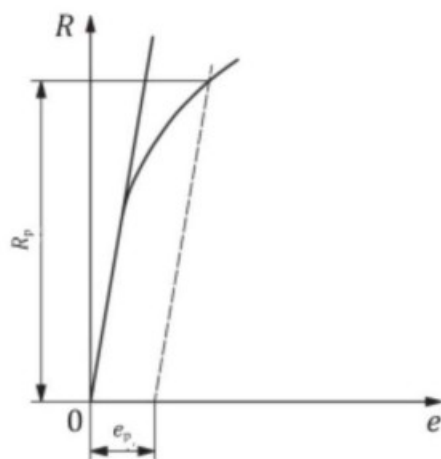
R_{eL} 下屈服强度

a Initial transient effect.

a 初始瞬态效应。

Figure 2 — Examples of upper and lower yield strengths for different types of curve

图 2 - 不同类型曲线的上屈服强度和下屈服强度示例



Key

关键

e percentage extension

伸长百分比

e_p specified percentage plastic extension

e_p 规定的塑性伸长百分比

R stress

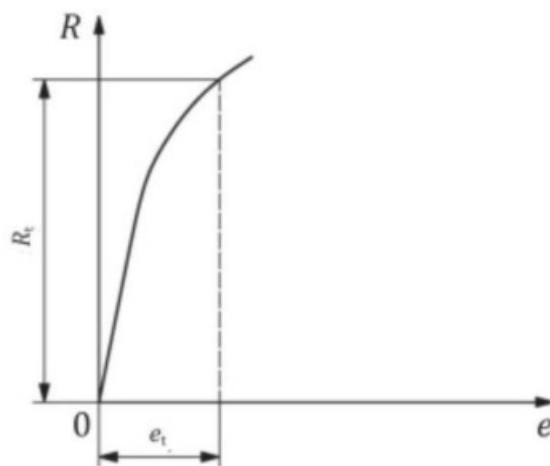
R 应力

R_p proof strength, plastic extension

R_p 规定强度、塑性延伸率

Figure 3 — Proof strength, plastic extension, R_p (see 13.1)

图 3 — 规定强度、塑性延伸率, R_p (见 13.1)



Key

键

e percentage extension

伸长率百分比

e_t percentage total extension

e_t 总伸长率百分比

R stress

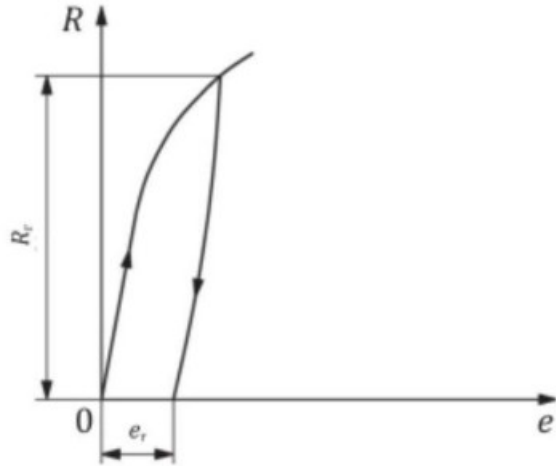
R 应力

R_t proof strength, total extension

规定强度、总延伸率

Figure 4 — Proof strength, total extension, R_t

图 4 — 规定强度、总延伸率, R_t



Key

键

e percentage elongation or percentage extension

e 伸长率百分比或延伸率百分比

e_r percentage permanent set extension or elongation

e_r 永久变形延伸率或伸长率百分比

R stress

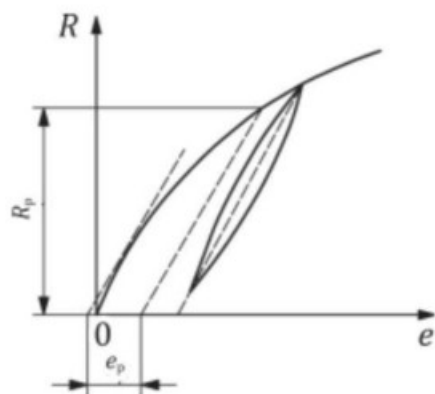
R 应力

R_r specified permanent set strength

R_r 规定永久变形强度

Figure 5 — Permanent set strength, R_r

图 5 — 永久变形强度, R_r



Key

键

e percentage extension

伸长率百分比

specified percentage plastic extension

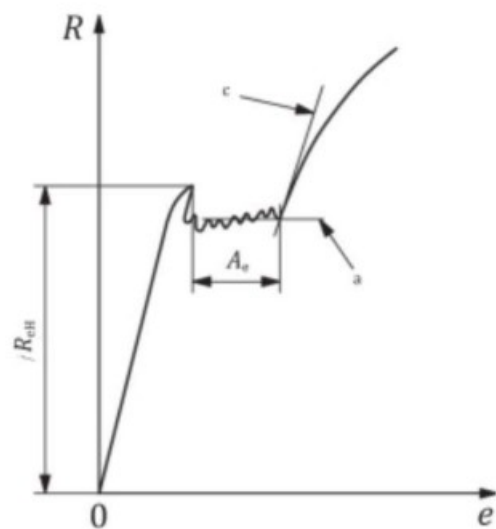
规定塑性伸长率百分比

R stress

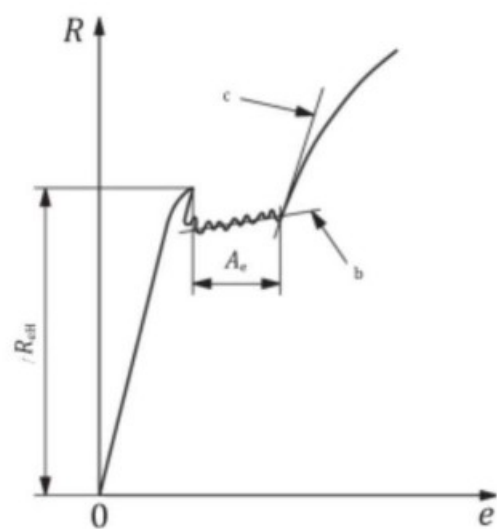
R 应力

R_p proof strength, plastic extension

R_p 规定塑性延伸强度



a) Horizontal line method



b) Regression method

Key

键

A_e percentage yield point extension

A_e 屈服点伸长率百分比

e percentage extension

伸长率百分比

R stress

R 应力

R_{eH} upper yield strength

R_{eH} 上屈服强度

a Horizontal line through the last local minimum point, prior to uniform work-hardening.

a 在均匀加工硬化之前，通过最后一个局部最低点的水平线。

b Regression line through the range of yielding, prior to uniform work-hardening.

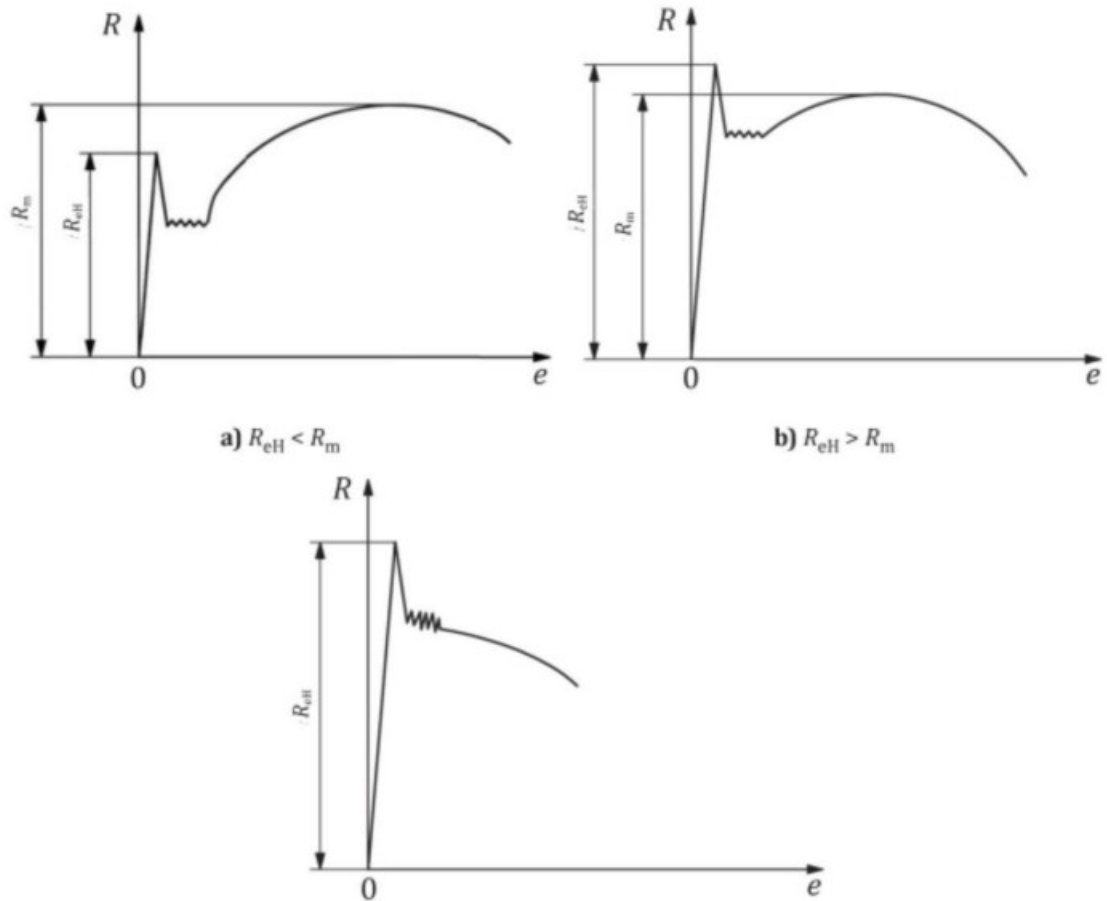
b 在均匀加工硬化之前，通过屈服范围的回归线。

Line corresponding to the highest slope of the curve occurring at the start of uniform work-hardening.

对应于均匀加工硬化开始时曲线最高斜率的线。

Figure 7 — Different evaluation methods for percentage yield point extension, A_e

图 7 — A_e 屈服点伸长率百分比的不同评估方法



c) Special case of stress-percentage extension behaviour ^a

c) 应力-伸长率行为的特殊情况 ^a

Key

键

e percentage extension

e 伸长率百分比

R stress

R 应力

R_{eH} upper yield strength

R_{eH} 上屈服强度

R_m tensile strength

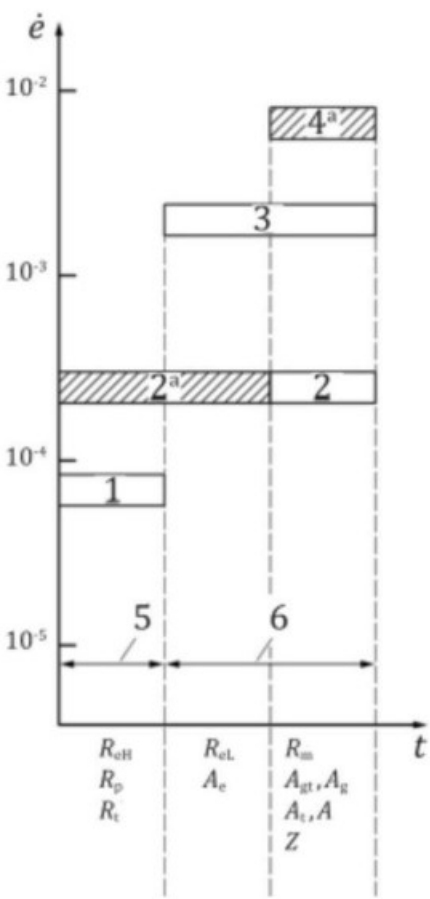
R_m 抗拉强度

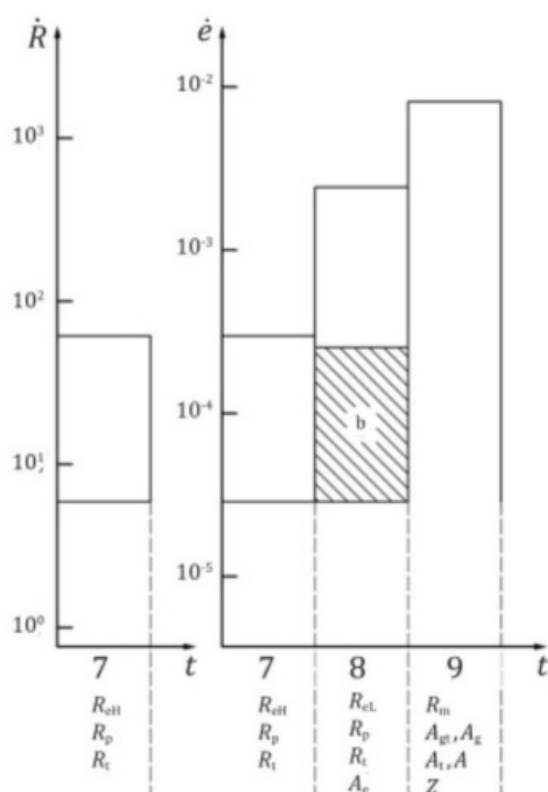
a For materials which display this behaviour, no tensile strength is defined according to this document. If necessary, separate agreements can be made between the parties concerned.

a 对于表现出这种行为的材料，本文件未定义抗拉强度。如有必要，相关方之间可另行达成协议。

Figure 8 — Different types of stress-extension curve for determination of tensile strength, R_m

图 8 — 用于测定抗拉强度的不同类型应力-伸长曲线， R_m





a) Method A b) Method B Key $\dot{\epsilon}$ strain rate, in s^{-1} 5 control mode: extensometer control (Method A1 closed loop) or crosshead control (Method A2 open loop) $\dot{R}$ stress rate, in $MPa s^{-1}$ t time 6 control mode: crosshead control (Method A2 open loop) 1 range 1: $\dot{\epsilon} = 0,00007 s^{-1}$, with a relative 7 elastic range of the test tolerance of $\pm 20\%$ 8 plastic range for the determination of R_{eL}, R_p, R_t, A_e 2 range 2: $\dot{\epsilon} = 0,00025 s^{-1}$, with a relative 9 maximum strain rate for the determination of R_m, A_{gt} , tolerance of $\pm 20\%$ A_g, A_t, A, Z 3 range 3: $\dot{\epsilon} = 0,002 s^{-1}$, with a relative a Recommended. tolerance of $\pm 20\%$ 4 range 4: $\dot{\epsilon} = 0,0067 s^{-1}$, with a relative b Expanded range to lower rates, if testing machine is tolerance of $\pm 20\%$ ($0,4 min^{-1}$, not capable of measuring or controlling the strain rate with a relative tolerance of $\pm 20\%$) (see 10.3.3.2.5). NOTE 1 Symbols refer to Table 1.

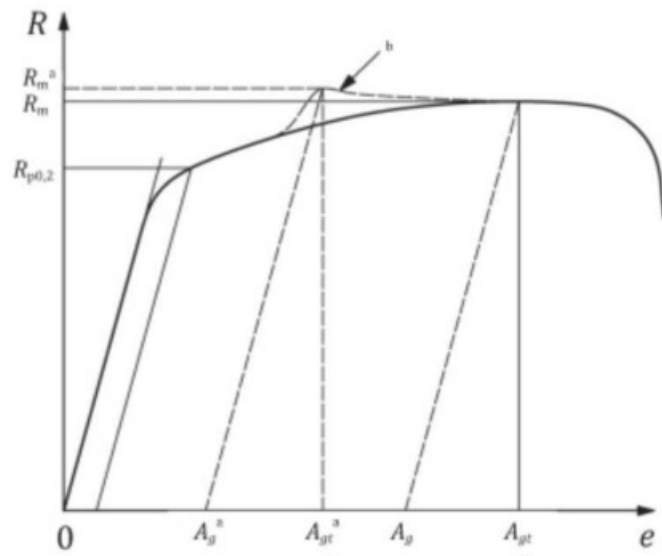
a) 方法 A b) 方法 B 关键 $\dot{\epsilon}$ 应变率，单位为 s^{-1} 5 控制模式:引伸计控制(方法 A1 闭环)或十字头控制(方法 A2 开环) $\dot{R}$ 应力率，单位为 $MPa s^{-1}$ t 时间 6 控制模式:十字头控制(方法 A2 开环) 1 范围 1: $\dot{\epsilon} = 0,00007 s^{-1}$ ，相对 7 试验弹性范围 公差为 $\pm 20\%$ 8 用于测定 R_{eL}, R_p, R_t, A_e 的塑性范围 2 范围 2: $\dot{\epsilon} = 0,00025 s^{-1}$ ，相对 9 用于测定 R_m, A_{gt} 的最大应变率，公差为 $\pm 20\%$ A_g, A_t, A, Z 3 范围 3: $\dot{\epsilon} = 0,002 s^{-1}$ ，相对 a 推荐。公差为 $\pm 20\%$ 4 范围 4: $\dot{\epsilon} = 0,0067 s^{-1}$ ，相对 b 如果试验机 公差为 $\pm 20\%$ ($0,4 min^{-1}$ ，无法以 $\pm 20\%$ 的相对公差测量或控制应变率，则扩展到较低速率范围 (见 10.3.3.2.5)。注 1 符号参见表 1。

NOTE 2 Strain rate in the elastic range for method B is calculated from stress rate using a Young's modulus of 210 000 MPa (steel).

注 2 方法 B 弹性范围内的应变率是根据应力率使用 210000MPa 的杨氏模量(钢)计算得出的。

Figure 9 — Illustration of strain rates to be used during the tensile test, if R_{eH} , R_{eL} , R_p , R_t , R_m , R_e , A_g , A_{gt} , A , A_t , and Z are determined

图 9 — 如果确定了 R_{eH} , R_{eL} , R_p , R_t , R_m , R_e 、 A_g , A_{gt} , A , A_t 和 Z ，拉伸试验期间使用的应变率示意图

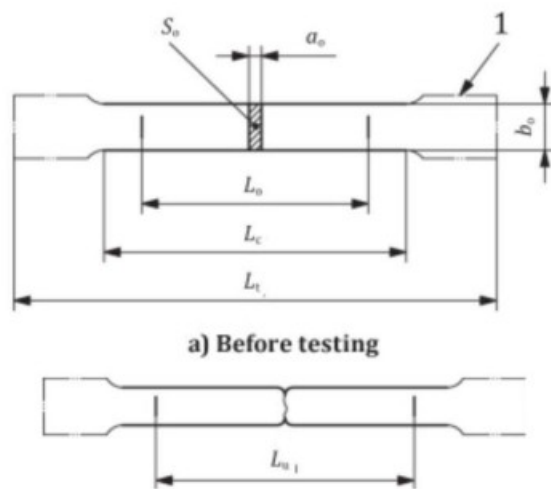


Key e percentage extension R stress a False values, resulting from an abrupt strain rate increase. Stress-strain behaviour, if strain rate is abruptly increased. NOTE For parameter definitions, see Table 1.

关键 e 伸长百分比 R 应力 a 由于应变率突然增加而产生的错误值。如果应变率突然增加，应力-应变行为。注 有关参数定义，参见表 1。

Figure 10 - Illustration of an inadmissible discontinuity in the stress-strain curve

图 10 - 应力-应变曲线中不可接受的不连续性示意图



b) After testing

b) 试验后

Key

关键

a_0 original thickness of a flat test piece or wall thickness of a tube

a_0 扁平试样的原始厚度或管材的壁厚

b_0 original width of the parallel length of a flat test piece

b_0 扁平试样平行长度的原始宽度

L_c parallel length

L_c 平行长度

L_0 original gauge length

L_0 原始标距长度

L_t total length of test piece

L_t 试件总长度

L_u final gauge length after fracture

L_u 断裂后最终标距长度

S_0 original cross-sectional area of the parallel length

S_0 平行长度段的原始横截面积

1 gripped ends

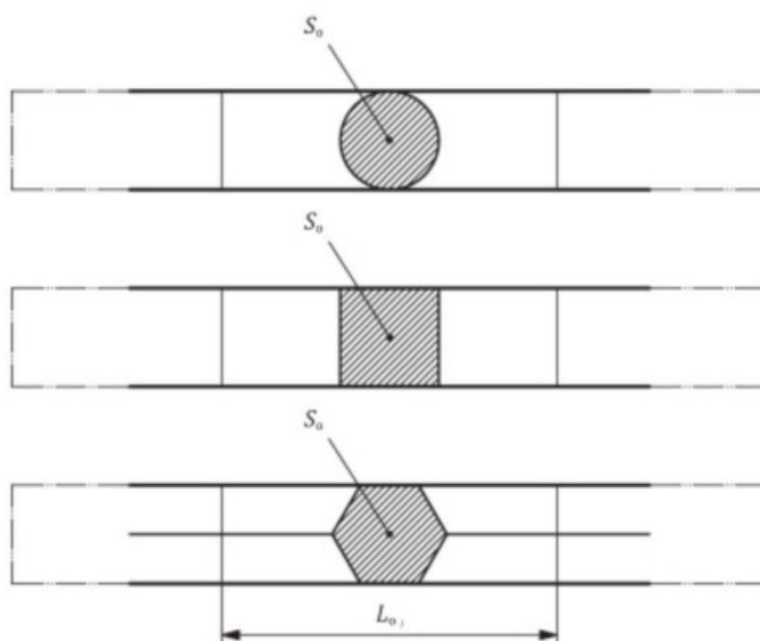
1 夹持端

NOTE The shape of the test-piece heads is only given as a guide.

注:试件头部形状仅作参考。

Figure 11 — Machined test pieces of rectangular cross-section (see Annexes B and D)

图 11 — 矩形横截面加工试件(见附录 B 和 D)



Key

键

L_0 original gauge length

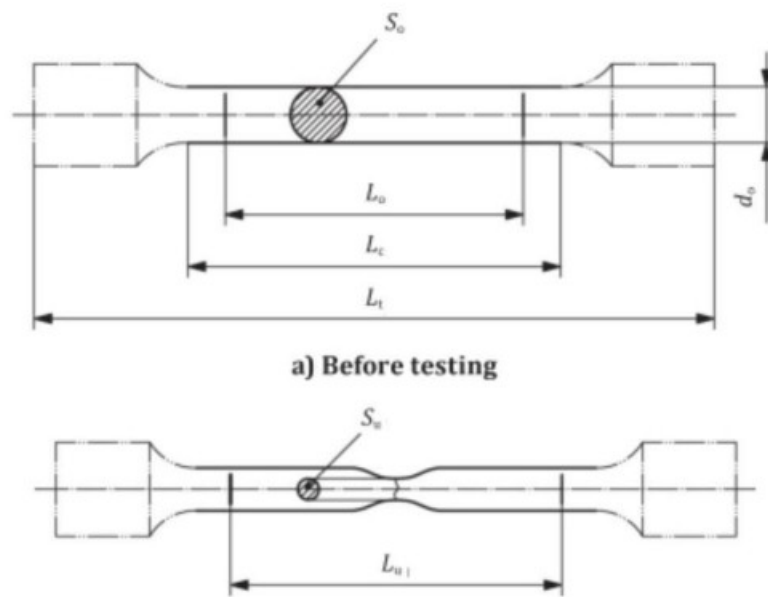
L_0 原始标距长度

S_0 original cross-sectional area

S_0 原始横截面积

Figure 12 — Test pieces comprising an unmachined portion of the product (see Annex C)

图 12 — 包含产品未加工部分的试件(见附录 C)



b) After testing

b) 试验后

Key

键

d_0 original diameter of the parallel length of a circular test piece

d_0 圆形试件平行长度段的原始直径

L_c parallel length

L_c 平行长度

L_0 original gauge length

L_0 原始标距长度

L_t total length of test piece

L_t 试件总长度

L_u final gauge length after fracture

L_u 断裂后的最终标距长度

S_0 original cross-sectional area of the parallel length

S_0 平行长度段的原始横截面积

S_u minimum cross-sectional area after fracture

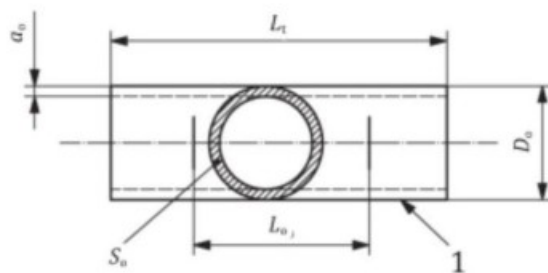
S_u 断裂后的最小横截面积

NOTE The shape of the test-piece heads is only given as a guide.

注:试件头部形状仅作参考。

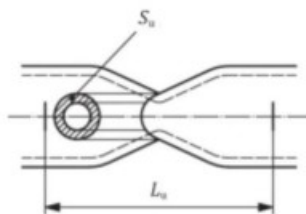
Figure 13 — Machined test pieces of round cross-section (see Annex D)

图 13 — 圆形横截面的加工试件(见附录 D)



a) Before testing

a) 试验前



b) After testing

b) 试验后

Key

键

a_0 original wall thickness of a tube

a_0 管材的原始壁厚

D_0 original external diameter of a tube

D_0 管材的原始外径

L_0 original gauge length

L_0 原始标距长度

L_t total length of test piece

L_t 试件的总长度

L_u final gauge length after fracture

L_u 断裂后的最终标距长度

S_0 original cross-sectional area of the parallel length

S_0 平行长度段的原始横截面积

S_u minimum cross-sectional area after fracture

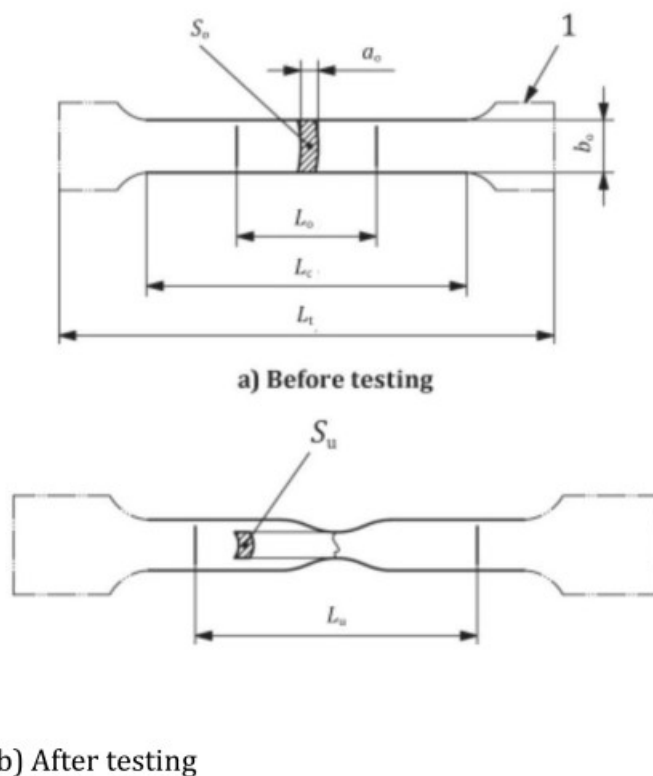
S_u 断裂后的最小横截面积

1 gripped ends

1 夹持端

Figure 14 — Test pieces comprising a length of tube (see Annex E)

图 14 — 由一段管材组成的试件(见附录 E)



b) 试验后

Key

关键

a_0 original wall thickness of a tube

a_0 管材的原始壁厚

b_0 original average width of the longitudinal strip taken from a tube

b_0 从管材上截取的纵向条带的原始平均宽度

L_c parallel length

L_c 平行长度

L_0 original gauge length

L_0 原始标距长度

L_t total length of test piece

L_t 试件的总长度

L_u final gauge length after fracture

L_u 断裂后的最终标距长度

S_0 original cross-sectional area of the parallel length

S_0 平行长度的原始横截面积

S_u minimum cross-sectional area after fracture

S_u 断裂后的最小横截面积

1 gripped ends

1 夹持端

NOTE The shape of the test-piece heads is only given as a guide.

注:试件头部的形状仅作示意。

Figure 15 — Test piece cut from a tube (see Annex E)

图 15 — 从管材上切割下来的试件(见附录 E)

Annex A

附录 A

(informative)

(资料性)

Recommendations concerning the use of computer-controlled tensile testing machines

关于使用计算机控制拉伸试验机的建议

A.1 General

A.1 总则

This annex contains additional recommendations for the determination of mechanical properties by using a computer-controlled tensile testing machine. In particular, it provides the recommendations that should be taken into account in the software and testing conditions.

本附录包含使用计算机控制拉伸试验机测定力学性能的补充建议。特别是，它提供了在软件和测试条件中应考虑的建议。

These recommendations are related to the design, the software of the machine and its validation, and to the operating conditions of the tensile test.

这些建议涉及试验机的设计、软件及其验证，以及拉伸试验的操作条件。

A.2 Tensile testing machine

A.2 拉伸试验机

A.2.1 Design

A.2.1 设计

The machine should be designed in order to provide outputs giving analogue signals untreated by the software. If such outputs are not provided, the machine manufacturer should give raw digital data with information on how these raw digital data have been obtained and treated by the software. They should be given in

basic SI units relating to the force, the extension, the crosshead separation, the time, and the test piece dimensions. An example of the format of suitable data files is given in Figure A.1.

试验机的设计应能提供未经软件处理的模拟信号输出。如果未提供此类输出，试验机制造商应给出原始数字数据，并提供有关这些原始数字数据如何获得以及如何由软件处理的信息。这些数据应以与力、伸长、十字头间距、时间和试样尺寸相关的基本国际单位给出。合适的数据文件格式示例见图 A.1。

```

A {
  "Reference"; "ISO 6892"
  "Identification"; "TENSTAND"
  "Material"; "DC 04 Steel"
  "Extensometer to crosshead transition"; 0.00; "%"
  "Specimen geometry"; "flat"
  "Specimen thickness = ao"
  "Specimen width = bo"
  "Cross-sectional area = So"
  "Extensometer gauge length = Le"
  "Extensometer output in mm"
  "Parallel length = Lc"
  "Data acquisition rate 50Hz"
  "Data row for start force reduction (Hysteresis) = Hs"
  "Data row for end force reduction (Hysteresis) = He"
  "Data row for switch to crosshead = Cs"
  "File length N data rows"
  "File width M data columns"
  .
  .
B {
  "ao"; 0.711; "mm"
  "bo"; 19.93; "mm"
  "So"; 14.17; "mm2"
  "Le"; 80.00; "mm"
  "Lc"; 120.00; "mm"
  "N"; 2912
  "M"; 4
  "Hs"; 0
  "He"; 0
  "Cs"; 0
  .
  .
C {
  "time"; "crosshead"; "extensometer"; "force"
  "s"; "mm"; "mm"; "kN"
  .
  .
  0.40; 0.0012; 0.0000; 0.12694
  0.42; 0.0016; 0.0000; 0.12992
  0.44; 0.0020; 0.0001; 0.13334
  0.46; 0.0024; 0.0002; 0.13699
  0.48; 0.0029; 0.0003; 0.14114
  0.50; 0.0035; 0.0004; 0.14620
  0.52; 0.0041; 0.0006; 0.15124
  0.54; 0.0047; 0.0007; 0.15669
  0.56; 0.0054; 0.0008; 0.16247
  0.58; 0.0060; 0.0009; 0.16794
  0.60; 0.0067; 0.0012; 0.17370
  0.62; 0.0074; 0.0013; 0.17980
  0.64; 0.0082; 0.0014; 0.18628
  .
  .

```

B test parameters and sample dimensions

B 测试参数和样品尺寸

Figure A.1 - Example of the format of suitable data files

图 A.1 - 合适数据文件格式示例

Key

关键

A header

A 标题

C data

C 数据

A.2.2 Data sampling frequency

A.2.2 数据采样频率

The frequency bandwidth of each of the measurement channels and the data sampling frequency should be sufficiently high to record the material characteristics to be measured. For example, to capture R_{eH} , Formula (A.1) may be used to determine the minimum sampling frequency, $f_{\min}$, in reciprocal seconds:

每个测量通道的频率带宽和数据采样频率应足够高，以记录要测量的材料特性。例如，为了捕获 R_{eH} ，可使用公式(A.1)来确定最小采样频率 $f_{\min}$ ，单位为每秒倒数：

$$f_{\min} = \frac{\dot{\epsilon} \cdot E}{R_{eH} \cdot q} \cdot 100 \quad (\text{A.1})$$

where

其中

$\dot{\epsilon}$ is the strain rate, in reciprocal seconds;

$\dot{\epsilon}$ 是应变率，单位为每秒倒数；

E is the modulus of elasticity, in megapascals;

E 为弹性模量，单位为兆帕斯卡；

R_{eH} is the upper yield strength, in megapascals;

R_{eH} 为上屈服强度，单位为兆帕斯卡；

q is the relative force measurement accuracy error, expressed as a percentage, of the testing machine (according to ISO 7500-1).

q 为试验机的相对力测量精度误差(根据 ISO 7500-1), 以百分比表示。

The choice of R_{eH} in Formula (A.1) is due to the fact that it corresponds to a transient characteristic during the test. If the material tested has no yield phenomena, the proof strength $R_{p0.2}$ should be used and the required minimum sampling frequency can be halved.

公式(A.1)中 R_{eH} 的选择是因为它对应于试验期间的一个瞬态特性。如果所测试的材料没有屈服现象, 则应使用规定强度 $R_{p0.2}$, 所需的最小采样频率可减半。

If method B (stress rate based) is used, the minimum sampling frequency should be calculated using Formula (A.2):

如果使用方法 B(基于应力速率), 则应使用公式(A.2)计算最小采样频率:

$$f_{\min} = \frac{\dot{R}}{R_{eH} \cdot q} \cdot 100 \quad (\text{A.2})$$

where $\dot{R}$ is the stress rate, in megapascals per second.

其中 $\dot{R}$ 为应力速率, 单位为兆帕斯卡每秒。

A.3 Determination of the mechanical properties

A.3 机械性能的测定

A.3.1 General

A.3.1 一般规定

The following requirements should be taken into account by the software of the machine.

试验机软件应考虑以下要求。

A.3.2 Upper yield strength

A.3.2 上屈服强度

R_{eH} (3.10.2.1) should be considered as the stress corresponding to the highest value of the force prior to a reduction of at least 0,5% of the force, and followed by a region in which the force should not exceed the previous maximum over a strain range not less than 0,05%.

R_{eH} (3.10.2.1)应被视为对应于力至少降低 0,5% 之前的力的最高值的应力，随后是一个区域，在该区域内，在不小于 0.05%的应变范围内，力不应超过先前的最大值。

A.3.3 Proof strength at plastic extension and proof strength at total extension

A.3.3 塑性延伸规定强度和总延伸规定强度

R_p (3.10.3) and R_t (3.10.4) can be determined by interpolation between adjacent points on the curve.

R_p (3.10.3) 和 R_t (3.10.4) 可通过曲线上相邻点之间的插值来确定。

A.3.4 Percentage total extension at maximum force

A.3.4 最大力下的总延伸率

A_{gt} (see 3.6.4 and Figure 1) should be considered as the total extension corresponding to the strain at maximum force.

A_{gt} (见 3.6.4 和图 1)应被视为对应于最大力下应变的总延伸率。

For some materials, it is necessary to smooth the stress-strain curve in which case a polynomial regression is recommended. The smoothing range may have an influence on the result. The smoothed curve should be a reasonable representation of the relevant part of the original stress-strain curve.

对于某些材料，有必要对应力 - 应变曲线进行平滑处理，在这种情况下，建议进行多项式回归。平滑范围可能会对结果产生影响。平滑后的曲线应合理表示原始应力 - 应变曲线的相关部分。

A.3.5 Percentage plastic extension at maximum force

A.3.5 最大力下的塑性延伸率

A_g (see 3.6.5 and Figure 1) should be considered as the plastic extension corresponding to the strain at maximum force.

A_g (见 3.6.5 和图 1)应被视为对应于最大力时应变的塑性延伸。

For some materials, it is necessary to smooth the stress-strain curve in which case a polynomial regression is recommended. The smoothing range may have an influence on the result. The smoothed curve should be a reasonable representation of the relevant part of the original stress-strain curve.

对于某些材料，有必要对应力 - 应变曲线进行平滑处理，在这种情况下建议采用多项式回归。平滑范围可能会对结果产生影响。平滑后的曲线应合理地表示原始应力 - 应变曲线的相关部分。

A.3.6 Percentage elongation at fracture

A.3.6 断裂伸长率

A.3.6.1 Determine A_t with reference to the definition of fracture in Figure A.2.

A.3.6.1 参照图 A.2 中对断裂的定义确定 A_t 。

The fracture is considered to be effective when the force between two consecutive points decreases

当两个连续点之间的力减小时，断裂被认为是有效的

a) by more than five times the difference between the value of the previous two points, followed by a decrease to lower than 2% of the maximum tensile force, and

a) 减小量超过前两个点的值之差的五倍，随后减小到低于最大拉力的 2%，并且

b) lower than 2% of the maximum tensile force (soft materials).

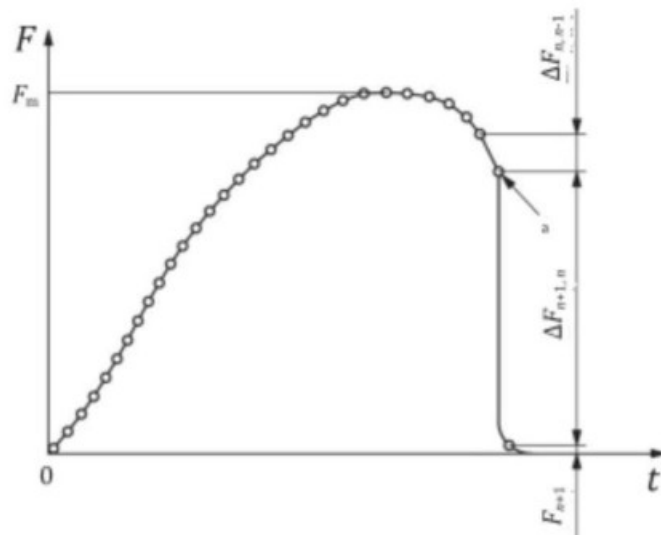
b) 低于最大拉力的 2%(软材料)。

An increased sampling rate and/or filtering of the force signal may influence the point of fracture determined according to this method.

提高采样率和/或对力信号进行滤波可能会影响根据此方法确定的断裂点。

Another useful method for detecting the fracture of the test piece is to monitor the voltage or electric current through the test piece, when the values measured just before the current is interrupted are taken as those at fracture.

另一种检测试件断裂的有用方法是监测通过试件的电压或电流，当电流中断前测量的值被视为断裂时的值。



Key

关键

F force at Fracture.

F 力 at 断裂。

F_m maximum force - data point

F_m 最大力 - 数据点

F_{n+1} force at measuring point $n + 1$ Criteria for fracture

F_{n+1} 测量点 $n + 1$ 处的力 断裂标准

$\Delta F_{n,n-1}$ force difference between measuring $|\Delta F_{n+1,n}| > 5|\Delta F_{n,n-1}|$ and/or

$\Delta F_{n,n-1}$ 测量 $|\Delta F_{n+1,n}| > 5|\Delta F_{n,n-1}|$ 与和/或之间的力差

point n and $n - 1$ $F_{n+1} < 0,02F_m$

点 n 和 $n - 1$ $F_{n+1} < 0,02F_m$

$\Delta F_{n+1,n}$ force difference between measuring

$\Delta F_{n+1,n}$ 测量点之间的力差

point $n + 1$ and n

点 $n + 1$ 和 n

t time

t 时间

Figure A.2 - Schematic representation for definition of fracture of the test piece

图 A.2 - 试件断裂定义的示意图

A.3.6.2 If the extensometer is kept on and the extension is measured until the fracture, evaluate the value at point 1 in Figure A. 2

A.3.6.2 如果引伸计保持开启状态并测量伸长量直至断裂，则评估图 A.2 中点 1 处的值。

A.3.6.3 If the extensometer is removed or if the extension measurement is interrupted before fracture but after maximum force, F_m , then it is permitted to use crosshead displacement to determine the additional elongation between removal of the extensometer and fracture. The method used should be verifiable.

A.3.6.3 如果引伸计被取下，或者在断裂前但在最大力 F_m 之后伸长量测量中断，那么允许使用十字头位移来确定引伸计取下至断裂之间的额外伸长量。所采用的方法应是可验证的。

A.3.7 Measurement of the slope of the curve in the elastic range

A.3.7 弹性范围内曲线斜率的测量

In order to be valid for test pieces of unknown characteristics, the method used should not rely upon any predefined stress limit, unless this is defined in the product standard or by agreement between parties to the test.

为了对特性未知的试件有效，所采用的方法不应依赖于任何预先定义的应力极限，除非在产品标准中定义或由试验各方商定。

Methods based on the calculation of the characteristics of a sliding segment are the most convenient. The parameters are the following:

基于计算滑动段特性的方法是最方便的。参数如下：

a) the length of the sliding segment (number of points used);

a) 滑动段的长度(使用的点数);

b) the formula chosen as reference to define the slope of the curve.

b) 选为定义曲线斜率参考的公式。

NOTE If the straight portion of the force extension curve is not clearly defined, refer to [13.1].

注 如果力 - 伸长曲线的直线部分未明确界定，请参考[13.1]。

The slope of the curve in the elastic range corresponds to the mean slope in a range where the following conditions are fulfilled:

弹性范围内曲线的斜率对应于满足以下条件的范围内的平均斜率：

- the slope of the sliding segment is constant;
- 滑动段的斜率是恒定的；
- the selected range is representative.
- 所选范围具有代表性。

In any case, it is recommended that pertinent limits for the range can be selected by the user in order to eliminate unrepresentative values of the slope of the curve in the elastic range.

在任何情况下，建议用户可以选择该范围的相关限值，以消除弹性范围内曲线斜率的无代表性值。

References to these and other acceptable methods are given in References [5], [17], [18], and [19].

参考文献[5]、[17]、[18]和[19]中给出了这些以及其他可接受方法的相关内容。

A recommended method to determine the slope of the elastic line for evaluation of $R_{n0.2}$ (Reference [20]) is given below.

下面给出一种推荐的用于确定弹性线斜率以评估 $R_{n0.2}$ 的方法(参考文献[20])。

— linear regression of the linear range;

— 线性范围的线性回归；

- lower limit: $\sim 10\%$ of $R_{p0.2}$;

- 下限: $R_{p0.2}$ 的 $\sim 10\%$;
- upper limit: $\sim 40\%$ of $R_{p0.2}$;
- 上限: $R_{p0.2}$ 的 $\sim 40\%$;
- to get more exact data for $R_{p0.2}$, the elastic line should be checked and if necessary recalculated with other limits.
- 为了获得关于 $R_{p0.2}$ 更精确的数据, 应检查弹性线, 如有必要, 用其他限值重新计算。

A.4 Validation of the software for determination of the tensile properties

A.4 拉伸性能测定软件的验证

The efficiency of the methods used by the testing system to determine the various material characteristics may be checked by comparison with results determined in the traditional manner by examination/calculation from plots of analogue or digital data. Data which are derived directly from the machine transducers or amplifiers should be collected and processed using equipment with frequency bandwidth, sampling frequency, and uncertainty of at least equal to those used to provide the machine computer-calculated results.

测试系统用于确定各种材料特性的方法的有效性, 可以通过与以传统方式从模拟或数字数据图进行检查/计算得出的结果进行比较来检验。应收集直接来自机器传感器或放大器的数据, 并使用频率带宽、采样频率和不确定度至少与用于提供机器计算机计算结果的设备相同的设备进行处理。

Confidence may be placed in the accuracy of the machine computer processing if differences in arithmetic means between computer-determined values and those determined manually on the same test piece are small. For the purposes of assessing the acceptability of such differences, five similar test pieces should be tested and the average difference for each relevant property should lie within the limits shown in Table A.1.

如果计算机确定的值与在同一试件上手动确定的值之间的算术平均值差异较小, 则可以相信机器计算机处理的准确性。为了评估这种差异的可接受性, 应测试五个相似的试件, 每个相关特性的平均差异应在表 A.1 所示的限值范围内。

NOTE This procedure confirms only that the machine finds the material characteristics for the particular test piece shape, material tested, and conditions

used. It gives no confidence that the properties of the material tested are either correct or fit for purpose.

注 此程序仅确认机器针对特定的试件形状、测试材料和使用条件找到了材料特性。它并不能让人相信所测试材料的特性是正确的或符合目的的。

If other methods are used, e.g. injection of a pre-determined set of data from a known material with a recognized level of quality assurance, these should meet the criteria mentioned above and those in Table A.1. As part of the EU-funded TENSTAND project (GBRD-CT-2000-00412), ASCII data files were produced with agreed values of tensile properties that may be used for validation of software. Further details are given in References [21] and [22].

如果使用其他方法，例如从具有公认质量保证水平的已知材料注入一组预先确定的数据，这些方法应符合上述标准以及表 A.1 中的标准。作为欧盟资助的 TENSTAND 项目(GBRD - CT - 2000 - 00412)的一部分，生成了具有商定拉伸性能值的 ASCII 数据文件，可用于软件验证。参考文献[21]和[22]中给出了更多详细信息。

Parameter	D^a		S^b	
	Relative ^c	Absolute ^c	Relative ^c	Absolute ^c
$R_{p0,2}$	$\leq 0.5 \%$	2MPa	$\leq 0.35 \%$	2 MPa
R_{p1}	$\leq 0,5 \%$	2MPa	$\leq 0,35 \%$	2MPa
R_{eH}	$\leq 1\%$	4 MPa	$\leq 0.35 \%$	2 MPa
$R_{el.}$	$\leq 0.5 \%$	2 MPa	$\leq 0.35 \%$	2 MPa
R_m	$\leq 0.5 \%$	2 MPa	$\leq 0.35 \%$	2MPa
A	-	$\leq 2\%$	-	$\leq 2\%$
参数	D^a		S^b	
	相对 ^c	绝对 ^c	相对 ^c	绝对 ^c
$R_{p0,2}$	$\leq 0.5 \%$	2MPa	$\leq 0.35 \%$	2 兆帕
R_{p1}	$\leq 0,5 \%$	2MPa	$\leq 0,35 \%$	2MPa
R_{eH}	$\leq 1\%$	4 兆帕	$\leq 0.35 \%$	2 兆帕
$R_{el.}$	$\leq 0.5 \%$	2 兆帕	$\leq 0.35 \%$	2 兆帕
R_m	$\leq 0.5 \%$	2 兆帕	$\leq 0.35 \%$	2MPa
A	-	$\leq 2\%$	-	$\leq 2\%$

Table A.1 — Maximum permitted differences between computer-derived and manually derived results where D_i is the difference between the result of manual evaluation, H_p and the result of computer evaluation, R_p for a test piece ($D_i = H_i - R_i$);

表 A.1 —— 计算机得出的结果与人工得出的结果之间的最大允许差值，其中 D_i 是对于试件 ($D_i = H_i - R_i$)，人工评估结果 H_p 与计算机评估结果 R_p 之间的差值；

n is the number of identical test pieces from one sample (≥ 5);

n 是来自一个样品(≥ 5)的相同试件数量；

The highest of the relative and absolute values should be taken into account.

应考虑相对值和绝对值中的最大值。

A.5 Computer compatible representation of standards

A.5 标准的计算机兼容表示

Computer Compatible Representation of Standards Computer readable data formats developed within the scope of the CEN/WS ELSSI-EMD offer an effective means to overcome systems interoperability issues and enable electronic reporting in the engineering materials sector. The findings of CEN/WS ELSSI-EMD, which aimed to establish the viability of defining data formats based on documentary Standards for mechanical testing, are reported in CWA 16200[42]. The guidelines that CWA 16200 describes for defining computer readable data formats based on a documentary testing standard have been applied to ISO 6892-1. The resulting definitions are available from the BSI Standards Resources server.

标准的计算机兼容表示 CEN/WS ELSSI-EMD 范围内开发的计算机可读数据格式提供了一种有效手段，可克服系统互操作性问题，并实现工程材料领域的电子报告。CEN/WS ELSSI-EMD 旨在确定基于机械测试文件标准定义数据格式的可行性，其研究结果报告在 CWA 16200[42]中。CWA 16200 描述的基于文件测试标准定义计算机可读数据格式的指南已应用于 ISO 6892-1。最终定义可从英国标准协会(BSI)标准资源服务器获取。

To demonstrate potential usage, CWA 16200 includes examples of the reporting capability for the data formats based on a tensile test carried out using a test piece manufactured from the Tensile Certified Reference Material CRM 661 (INGELBRECHT and LOVEDAY 2000[29]) carried out as part of the TENSTAND Project (RIDES and LORD, 2005[21]).

为展示潜在用途，CWA 16200 包括基于使用由拉伸认证参考材料 CRM 661(INGELBRECHT 和 LOVEDAY, 2000[29])制造的试件进行的拉伸试验的数据格式报告能力示例，该试验作为 TENSTAND 项目(RIDES 和 LORD, 2005[21])的一部分进行。

Annex B

附录 B

(normative)

(规范性)

Types of test pieces to be used for thin products: sheets, strips, and flats between 0,1 mm and 3 mm thick

用于薄产品的试件类型:厚度在 0.1 毫米至 3 mm 之间的板材、带材和平板

B.1 General

B.1 总则

For products of less than 0,5 mm thickness, special precautions can be necessary.

对于厚度小于 0.5 毫米的产品，可能需要采取特殊预防措施。

B.2 Shape of the test piece

B.2 试件形状

Generally, the test piece has gripped ends which are wider than the parallel length. The parallel length, L_c , shall be connected to the ends by means of transition curves with a radius of at least 20 mm. The width of these ends should be $\geq 1,2b_0$, where b_0 is the original width.

通常，试件有比平行长度更宽的夹持端。平行长度 L_c 应通过半径至少为 20 mm 的过渡曲线与端部相连。这些端部的宽度应为 $\geq 1,2b_0$ ，其中 b_0 是原始宽度。

By agreement, the test piece may also consist of a strip with parallel sides (parallel sided test piece). For products of width equal to or less than 20 mm, the width of the test piece may be the same as that of the product.

经协议，试件也可由具有平行边的带材组成(平行边试件)。对于宽度等于或小于 20 mm 的产品，试件宽度可与产品宽度相同。

B.3 Dimensions of the test piece

B.3 试件尺寸

Three different non-proportional test piece geometries are widely used (see Table B.1).

广泛使用三种不同的非比例试件几何形状(见表 B.1)。

The parallel length shall not be less than $L_0 + b_0/2$.

平行长度不得小于 $L_0 + b_0/2$ 。

In case of dispute, the length $L_0 + 2b_0$ should be used, unless there is insufficient material.

如有争议，应采用长度 $L_0 + 2b_0$ ，除非材料不足。

For parallel side test pieces less than 20 mm wide, and unless otherwise specified in the product standard, the original gauge length, L_c , shall be equal to 50 mm. For this type of test piece, the free length between the grips shall be equal to $L_0 + 3b_0$.

对于宽度小于 20 mm 的平行边试件，除非产品标准另有规定，原始标距长度 L_c 应等于 50 mm。对于此类试件，夹具之间的自由长度应等于 $L_0 + 3b_0$ 。

When measuring the dimensions of each test piece, the tolerances on shape given in Table B.2 shall apply.

测量每个试件的尺寸时，应采用表 B.2 中给出的形状公差。

For test pieces where the width is the same as that of the product, the original cross-sectional area, S_0 , shall be calculated on the basis of the measured dimensions of the test piece.

对于宽度与产品相同的试件，原始横截面积 S_0 应根据试件的测量尺寸计算。

The nominal width of the test piece may be used, provided that the machining tolerances and tolerances on shape given in Table B.2 have been complied with, to avoid measuring the width of the test piece before the test.

如果符合表 B.2 中给出的加工公差和形状公差，则可以使用试件的标称宽度，以避免在试验前测量试件的宽度。

Table B.1 - Dimensions of test pieces

表 B.1 - 试件尺寸

Dimensions in millimetres

单位为毫米的尺寸

Test piece type	Width b_0	Original gauge length L_0	Parallel length L_c		Free length between the grips for parallel sided test piece
			Minimum	Recommended	
1	12,5 ± 1	50	57	75	87,5
2	20 ± 1	80	90	120	140
3	25 ± 1	50 ^a	60°	-	Not defined
试件类型	宽度 b_0	原始标距长度 L_0	平行长度 L_c		平行边试件夹头间的自由长度
			最小值	推荐值	
1	12,5 ± 1	50	57	75	87,5
2	20 ± 1	80	90	120	140
3	25 ± 1	50 ^a	60°	-	未定义

a The ratio L_0/b_0 and L_c/b_0 of a type 3 test piece in comparison to one of types 1 and 2 is very low. As a result, the properties, especially the elongation after fracture (absolute value and scatter range), measured with this test piece, will

a 与 1 型和 2 型试件之一相比, 3 型试件的 L_0/b_0 和 L_c/b_0 比率非常低。因此, 用该试件测量的性能, 特别是断裂后伸长率(绝对值和分散范围), 将

be different from the other test piece types.

与其他类型的试件不同。

Table B.2 - Tolerances on the width of the test piece Dimensions and tolerances in millimetres

表 B.2 - 试件宽度的公差 尺寸和公差(单位:毫米)

Nominal width of the test piece	Machining tolerance ^a	Tolerance on shape ^b
12,5	$\pm 0,05$	0,06
20	$\pm 0,10$	0,12
25	$\pm 0,10$	0,12
试件的公称宽度	加工公差 ^a	形状公差 ^b
12,5	$\pm 0,05$	0,06
20	$\pm 0,10$	0,12
25	$\pm 0,10$	0,12

a These tolerances are applicable if the nominal width of the test piece is to be used in the calculation of the original cross-sectional area, S_0 , without having to measure the width of each test piece.

a 如果要在计算原始横截面积时使用试件的标称宽度 S_0 ，而无需测量每个试件的宽度，则适用这些公差。

b Maximum deviation between the measurements of the width along the entire parallel length, L_c , of the test piece.

b 沿试件整个平行长度 L_c 测量的宽度之间的最大偏差。

B.4 Preparation of test pieces

B.4 试件制备

The test pieces shall be prepared so as not to affect the properties of the sample. Any areas which have been hardened by shearing or punching, if it affects the properties, shall be removed by machining. These test pieces are predominantly prepared from sheet or strip. If possible, the as-rolled surfaces should not be removed.

试件的制备应不影响样品的性能。任何因剪切或冲孔而硬化的区域，若影响性能，应通过机械加工去除。这些试件主要由板材或带材制备。如有可能，不应去除轧制表面。

The preparation of these test pieces by punching can result in significant changes to the material properties, especially the yield/proof strength (due to work-hardening). Materials which exhibit high work-hardening should, generally, be prepared by milling, grinding, etc.

通过冲孔制备这些试件可能会导致材料性能发生显著变化，尤其是屈服/规定塑性延伸强度(由于加工硬化)。一般来说，表现出高加工硬化的材料应通过铣削、磨削等方法制备。

For very thin materials, it is recommended that strips of identical widths should be cut and assembled into a bundle with intermediate layers of a paper which is resistant to the cutting oil. Each small bundle of strips should then be assembled with a thicker strip on each side, before machining to the final dimensions of the test piece.

对于非常薄的材料，建议切割相同宽度的条带，并将其与耐切削油的纸张中间层组装成一捆。然后，在将每个小条带捆加工成试件的最终尺寸之前，应在其两侧各组装一条较厚的条带。

The tolerance given in Table B.2, e.g. $\pm 0,05$ mm for a nominal width of 12,5 mm, means that no test piece shall have a width outside the two values given below, if the nominal value of the original cross-sectional area, S_0 , is to be included in the calculation without having to measure it.

表 B.2 中给出的公差，例如对于标称宽度 12,5 mm 为 $\pm 0,05$ mm，意味着如果要在计算中包含原始横截面积 S_0 的标称值而无需测量它，则任何试件的宽度均不得超出以下给出的两个值之外。

$$-12,5 \text{ mm} + 0,05 \text{ mm} = 12,55 \text{ mm}$$

$$-12,5 \text{ mm} - 0,05 \text{ mm} = 12,45 \text{ mm}$$

B.5 Determination of the original cross-sectional area

B.5 原始横截面积的测定

S_0 shall be calculated from measurements of the dimensions of the test piece or by assumption of good machining practice (see footnote a of Table B.2).

S_0 应根据试件尺寸的测量值或通过假定良好的加工规范来计算(见表 B.2 脚注 a)。

The error in determining the original cross-sectional area shall not exceed $\pm 2\%$. As the greatest part of this error normally results from the measurement of the thickness of the test piece, the error in measurement of the width shall not exceed $\pm 0,2\%$.

测定原始横截面积的误差不得超过 $\pm 2\%$ 。由于该误差的最大部分通常来自试件厚度的测量，宽度测量的误差不得超过 $\pm 0,2\%$ 。

In order to achieve test results with a reduced measurement uncertainty, it is recommended that the original cross-sectional area be determined with an accuracy of $\pm 1\%$ or better. For thin materials, special measurement techniques can be required.

为了获得测量不确定度降低的试验结果，建议以 $\pm 1\%$ 或更高的精度测定原始横截面积。对于薄材料，可能需要特殊的测量技术。

Annex C

附录 C

(normative)

(规范性)

Types of test pieces to be used for wire, bars, and sections with a diameter or thickness of less than 4 mm

用于直径或厚度小于 4 mm 的线材、棒材和型材的试件类型

C.1 Shape of the test piece

C.1 试件形状

The test piece generally consists of an unmachined portion of the product (see Figure 12).

试件通常由产品的未加工部分组成(见图 12)。

C.2 Dimensions of the test piece

C.2 试件尺寸

The original gauge length, L_0 , shall be taken as $200\text{ mm} \pm 2\text{ mm}$ or $100\text{ mm} \pm 1\text{ mm}$. The distance between the grips of the machine shall be equal to at least $L_0 + 3b_0$ but a minimum of $L_0 + 20\text{ mm}$.

原始标距, L_0 , 应取为 $200\text{ mm} \pm 2\text{ mm}$ 或 $100\text{ mm} \pm 1\text{ mm}$ 。试验机夹具之间的距离应至少等于 $L_0 + 3b_0$, 但最小为 $L_0 + 20\text{ mm}$ 。

If the percentage elongation after fracture is not to be determined, a distance between the grips of at least 50 mm may be used.

如果不测定断裂后伸长率, 则可使用夹具之间至少为 50 mm 的距离。

C.3 Preparation of test pieces

C.3 试件制备

If the product is delivered coiled, care shall be taken in straightening it.

如果产品以卷材形式交付, 矫直时应小心操作。

C.4 Determination of the original cross-sectional area

C.4 原始横截面积的测定

Determine S_0 to an accuracy of $\pm 1\%$ or better.

将 S_0 测定至 $\pm 1\%$ 或更高的精度。

For products of circular cross-section, the original cross-sectional area may be calculated from the arithmetic mean of two measurements carried out in two perpendicular directions.

对于圆形横截面的产品，原始横截面积可根据在两个垂直方向上进行的两次测量的算术平均值计算得出。

The original cross-sectional area, S_0 , in square millimetres, may be determined from the mass of a known length and its density using Formula (C.1):

原始横截面积 S_0 ，以平方毫米为单位，可使用公式 (C.1) 根据已知长度的质量及其密度确定：

$$S_0 = \frac{1000 \cdot m}{\rho \cdot L_t} \quad (\text{C.1})$$

where

其中

m is the mass, in grams, of the test piece;

m 是试件的质量，以克为单位；

ρ is the density, in grams per cubic centimetre, of the test piece material;

ρ 是试件材料的密度，以克每立方厘米为单位；

L_t is the total length, in millimetres, of the test piece.

L_t 是试件的总长度，以毫米为单位。

Annex D

附录 D

(normative)

(规范性附录)

Types of test pieces to be used for sheets and flats of thickness equal to or greater than 3 mm and wire, bars, and sections of diameter or thickness equal to or greater than 4 mm

厚度等于或大于 3 mm 的板材和平板以及直径或厚度等于或大于 4 mm 的线材、棒材和型材所使用的试件类型

D.1 Shape of the test piece

D.1 试件形状

Usually, the test piece is machined and the parallel length shall be connected by means of transition radii to the gripped ends which may be of any suitable shape for the grips of the testing machine (see Figure 13). The minimum transition radius between the gripped ends and the parallel length shall be the following:

通常，试件需进行加工，平行长度段应通过过渡半径与夹持端相连，夹持端可为试验机夹具适用的任何合适形状(见图 13)。夹持端与平行长度段之间的最小过渡半径应如下：

a) $0,75d_0$, where d_0 is the diameter of the parallel length, for the cylindrical test pieces;

a) $0,75d_0$ ，其中 d_0 为平行长度段的直径，适用于圆柱形试件；

b) 12 mm for other test pieces.

b) 其他试件为 12 mm 。

Sections, bars, etc. may be tested unmachined, if required.

如有需要，型材、棒材等可不经加工进行试验。

The cross-section of the test piece may be circular, square, rectangular or, in special cases, of another shape.

试件的横截面可以是圆形、方形、矩形，特殊情况下也可以是其他形状。

For test pieces with a rectangular cross-section, the width to thickness ratio should not exceed 8:1.

对于矩形横截面的试件，宽厚比不应超过 8:1。

In general, the diameter of the parallel length of machined cylindrical test pieces shall be not less than 3 mm .

一般来说，加工后的圆柱形试件平行长度段的直径应不小于 3 mm 。

D.2 Dimensions of the test piece

D.2 试件尺寸

D.2.1 Parallel length of machined test piece

D.2.1 加工后试件的平行长度段

The parallel length, L_c , shall be at least equal to:

平行长度 L_c 应至少等于:

- a) $L_0 + (d_0/2)$ for cylindrical test pieces;
- a) 圆柱形试件为 $L_0 + (d_0/2)$;
- b) $L_0 + 1,5\sqrt{S_0}$ for proportional test pieces other than cylindrical test pieces;
- b) 除圆柱形试件外的比例试件为 $L_0 + 1,5\sqrt{S_0}$;
- c) $L_0 + (b_0/2)$ for non-proportional test pieces (see Table D.2).
- c) 非比例试件为 $L_0 + (b_0/2)$ (见表 D.2)。

In case of dispute, the length $L_0 + 2d_0$ or $L_0 + 2\sqrt{S_0}$ shall be used depending on the type of test piece, unless there is insufficient material.

如有争议，除非材料不足，应根据试件类型使用长度 $L_0 + 2d_0$ 或 $L_0 + 2\sqrt{S_0}$ 。

D.2.2 Length of unmachined test piece

D.2.2 未加工试件的长度

The free length between the grips of the machine shall be adequate for the gauge marks to be at least a distance of $\sqrt{S_0}$ from the grips.

试验机夹头之间的自由长度应足够，以使标距标记与夹头之间至少保持 $\sqrt{S_0}$ 的距离。

D.2.3 Original gauge length

D.2.3 原始标距长度

D.2.3.1 Proportional test pieces

D.2.3.1 比例试样

As a general rule, proportional test pieces are used where L_0 is related to the original cross-sectional area, S_0 , by Formula (D.1):

一般来说，当 L_0 与原始横截面积 S_0 通过公式(D.1)相关时，使用比例试样：

$$L_0 = k\sqrt{S_0} \quad (\text{D.1})$$

where k is equal to 5,65 .

其中 k 等于 5.65。

Alternatively, 11,3 may be used as the k value.

或者，11.3 可用作 k 值。

Test pieces of circular cross-section should preferably have one set of dimensions given in Table D.1.

圆形横截面的试样最好具有表 D.1 中给出的一组尺寸。

Table D.1 - Circular cross-section test pieces

表 D.1 - 圆形横截面试样

Coefficient of proportionality k	Diameter d mm	Original gauge length $L_0 = k\sqrt{S_0}$ mm	Minimum parallel length L_c mm
5,65	20	100	110
	14	70	77
	10	50	55
	5	25	28
比例系数 k	直径 d 毫米	原始标距长度 $L_0 =$	最小平行长度 L_c 毫

		$k\sqrt{S_0}$ 毫米	米
5,65	20	100	110
	14	70	77
	10	50	55
	5	25	28

D.2.3.2 Non-proportional test pieces

D.2.3.2 非比例试样

Non-proportional test pieces may be used if specified by the product standard.

如果产品标准有规定，可以使用非比例试样。

The parallel length, L_c , should not be less than $L_0 + b_0/2$. In case of dispute, the parallel length $L_c = L_0 + 2b_0$ shall be used unless there is insufficient material.

平行长度， L_c ，不应小于 $L_0 + b_0/2$ 。如有争议，除非材料不足，应使用平行长度 $L_c = L_0 + 2b_0$ 。

Table D. 2 gives details of some typical test piece dimensions.

表 D.2 给出了一些典型试样尺寸的详细信息。

Table D.2 — Typical flat test piece dimensions

表 D.2 — 典型平板试样尺寸

Dimensions in millimetres

尺寸单位为毫米

Width b_0	Original gauge length L_0	Minimum parallel length L_c	Approximately total length L_t
40 $\pm 0,7$	200	220	450
25 $\pm 0,7$	200	212,5	450
20 $\pm 0,5$	80	90	300
宽度 b_0	原始标距长度 L_0	最小平行长度 L_c	大约总长度 L_t
40 $\pm 0,7$	200	220	450

25 ± 0,7	200	212,5	450
20 ± 0,5	80	90	300

D.3 Preparation of test pieces

D.3 试件制备

D.3.1 General

D.3.1 一般规定

The tolerances on the transverse dimensions of machined test pieces are given in Table D.3.

加工后试件横向尺寸的公差见表 D.3。

An example of the application of these tolerances is given in D.3.2 and D.3.3.

D.3.2 和 D.3.3 给出了这些公差应用的示例。

D.3.2 Machining tolerances

D.3.2 加工公差

The value given in Table D.3, e.g. ±0,03 mm for a nominal diameter of 10 mm, means that no test piece shall have a diameter outside the two values given below, if the nominal value of the original cross-sectional area, S_0 , is to be used in the calculation of results without having to measure each test piece.

表 D.3 中给出的值，例如对于标称直径为 10 mm 的 ±0,03 mm，意味着如果在计算结果时要使用原始横截面积 S_0 的标称值而无需测量每个试件，则任何试件的直径均不得超出以下给出的两个值之外。

$$- 10 \text{ mm} + 0,03 \text{ mm} = 10,03 \text{ mm}$$

$$- 10 \text{ mm} - 0,03 \text{ mm} = 9,97 \text{ mm}$$

D.3.3 Tolerances on shape

D.3.3 形状公差

The value given in Table D. 3 means that, for a test piece with a nominal diameter of 10 mm which satisfies the machining conditions given above, the deviation between the smallest and largest diameters measured shall not exceed 0,04 mm.

表 D.3 中给出的值意味着，对于标称直径为 10 mm 且满足上述加工条件的试件，所测量的最小直径与最大直径之间的偏差不得超过 0.04mm。

Consequently, if the minimum diameter of this test piece is 9,99 mm , its maximum diameter shall not exceed $9,99 \text{ mm} + 0,04 \text{ mm} = 10,03 \text{ mm}$.

因此，如果该试件的最小直径为 9,99 mm ，则其最大直径不得超过 $9,99\text{mm} + 0,04\text{mm} = 10,03\text{mm}$ 。

Designation	Nominal transverse dimension	Machining tolerance on the nominal dimension	Tolerance on shape ^b
Diameter of machined test pieces of circular cross-section and transverse dimensions of test pieces of rectangular cross-section machined on all four sides	$23 \leq 6$	$\pm 0,02$	0,03
	$>6 \leq 10$	$\pm 0,03$	0,04
	$>10 \leq 18$	$\pm 0,05$	0,04
	$>18 \leq 30$	$\pm 0,10$	0,05
Transverse dimensions of test pieces of rectangular cross-section machined on only two opposite sides	$23 \leq 6$	$\pm 0,02$	0,03
	$>6 \leq 10$	$\pm 0,03$	0,04
	$>10 \leq 18$	$\pm 0,05$	0,06
	$>18 \leq 30$	$\pm 0,10$	0,12
	$>30 \leq 50$	$\pm 0,15$	0,15
名称	公称横向尺寸	公称尺寸的加工公差	形状公差 ^b
圆形横截面加工试件的直径以及四边均加工的矩形横截面试件的横向尺寸	$23 \leq 6$	$\pm 0,02$	0,03
	$>6 \leq 10$	$\pm 0,03$	0,04
	$>10 \leq 18$	$\pm 0,05$	0,04
	$>18 \leq 30$	$\pm 0,10$	0,05
仅在两个相对面加工的矩形横截面试件的横向尺寸	$23 \leq 6$	$\pm 0,02$	0,03
	$>6 \leq 10$	$\pm 0,03$	0,04
	$>10 \leq 18$	$\pm 0,05$	0,06

	>18 \$30	$\pm 0,10$	0,12
	>30 ≤ 50	$\pm 0,15$	0,15

Table D.3 — Tolerances relating to the transverse dimensions of test pieces
Dimensions and tolerances in millimetres a These tolerances are applicable if the nominal transverse dimensions of machined test piece are to be used in the calculation of the original cross-sectional area, S_0 , without having to measure the transverse dimensions of each test piece. If these machining tolerances are not complied with, it is essential to measure every individual test piece. b Maximum deviation between the measurements of a specified transverse dimension along the entire parallel length, L_c , of the test piece.

表 D.3——与试件横向尺寸相关的公差 尺寸及公差(单位:毫米) a 如果在计算原始横截面积时要使用加工后试件的标称横向尺寸, S_0 , 而无需测量每个试件的横向尺寸, 则适用这些公差。如果不符合这些加工公差, 则必须测量每个单独的试件。 b 沿试件整个平行长度 L_c 测量的指定横向尺寸之间的最大偏差。

D.4 Determination of the cross-sectional area

D.4 横截面积的测定

The nominal dimensions can be used to calculate S_0 for test pieces of circular cross-section and rectangular cross-section machined on all four sides that satisfy the tolerances given in Table D.3. For all other shapes of test pieces, the original cross-sectional area shall be calculated from measurements of the appropriate dimensions, with an error not exceeding $\pm 0,5$ % on each dimension.

对于圆形横截面和四边均经过加工且满足表 D.3 中给出公差的矩形横截面的试件, 可以使用标称尺寸来计算 S_0 。对于所有其他形状的试件, 应根据适当尺寸的测量值计算原始横截面积, 每个尺寸的误差不超过 $\pm 0.5\%$ 。

Annex E

附录 E

(normative)

(规范性附录)

Types of test pieces to be used for tubes

管材所用试件的类型

E.1 Shape of the test piece

E.1 试件形状

The test piece consists either of a length of tube, or a longitudinal or transverse strip cut from the tube and having the full thickness of the wall tube (see Figures 14 and 15), or of a test piece of circular cross-section machined from the wall of the tube.

试件可以是一段管材，或者是从管材上切割下来的具有管壁全厚度的纵向或横向条带(见图 14 和图 15)，或者是从管壁加工而成的圆形横截面试件。

Machined transverse, longitudinal, and circular cross-section test pieces are described in Annex B for tube wall thickness less than 3 mm , and in Annex D for thickness equal to or greater than 3 mm . The longitudinal strip is generally used for tubes with a wall thickness of more than 0,5 mm .

对于管壁厚度小于 3 mm 的情况，加工后的横向、纵向和圆形横截面试件在附录 B 中有描述；对于厚度等于或大于 3 mm 的情况，在附录 D 中有描述。纵向条带通常用于壁厚大于 0,5 mm 的管材。

E.2 Dimensions of the test piece

E.2 试件尺寸

E.2.1 Length of tube

E.2.1 管材长度

The tube length may be plugged at both ends. The free length between each plug and the nearest gauge marks shall be greater than $D_0/4$. In case of dispute, the value, D_0 , shall be used, if there is sufficient material.

管材两端可以封堵。每个封堵与最近的标距标记之间的自由长度应大于 $D_0/4$ 。如有争议，如果有足够的材料，应使用 D_0 这个值。

The length of the plug projecting beyond the grips of the machine in the direction of the gauge marks shall not exceed D_0 , and its shape shall be such that it does not interfere with deformation of the gauge length.

封堵在标距标记方向上伸出试验机夹具的长度不应超过 D_0 ，其形状应确保不会干扰标距长度的变形。

E.2.2 Longitudinal or transverse strip

E.2.2 纵向或横向条带

The parallel length, L_c , of the longitudinal strips shall not be flattened but the heads may be flattened for gripping in the testing machine.

纵向条带的平行长度 L_c 不应压扁，但头部可以压扁以便在试验机中夹持。

Transverse or longitudinal test piece dimensions other than those given in Annexes B and D can be specified in the product standard.

除附录 B 和附录 D 中给出的尺寸外，横向或纵向试件的尺寸可在产品标准中规定。

Special precautions shall be taken when straightening the transverse test pieces.

矫直横向试件时应采取特殊预防措施。

E.2.3 Circular cross-section test piece machined in tube wall

E.2.3 管壁上车削加工的圆形横截面试件

The sampling of the test pieces is specified in the product standard.

试件的取样在产品标准中规定。

E.3 Determination of the original cross-sectional area

E.3 原始横截面积的测定

S_0 for the test piece shall be determined to the nearest $\pm 1\%$ or better.

试件的 S_0 应精确到最接近的 $\pm 1\%$ 或更高精度。

The original cross-sectional area, S_0 , in square millimetres, of the length of tube or longitudinal or transverse strip may be determined from the mass of the test piece, the length of which has been measured, and from its density using Formula (E.1):

管材、纵向或横向条带长度的原始横截面积 S_0 (单位为平方毫米), 可根据已测量长度的试件质量及其密度, 使用公式(E.1)确定:

$$S_0 = \frac{1000m}{\rho L_t} \quad (\text{E.1})$$

where

式中

m is the mass, in grams, of the test piece;

m 为试件质量, 单位为克;

ρ is the density, in grams per cubic centimetre, of the test piece material;

ρ 为试件材料的密度, 单位为克每立方厘米;

L_t is the total length, in millimetres, of the test piece.

L_t 为试件的总长度, 单位为毫米。

The original cross-sectional area, S_0 , of a test piece consisting of a longitudinal sample shall be calculated according to Formula (E.2):

由纵向试样组成的试件的原始横截面积 S_0 , 应按公式(E.2)计算:

$$S_0 = \frac{b_o}{4} (D_o^2 - b_o^2)^{1/2} + \frac{D_o^2}{4} \arcsin\left(\frac{b_o}{D_o}\right) - \frac{b_o}{4} [(D_o - 2a_o)^2 - b_o^2]^{1/2} - \left(\frac{D_o - 2a_o}{2}\right)^2 \arcsin\left(\frac{b_o}{D_o - 2a_o}\right) \quad (\text{E.2})$$

where

式中

b_0 is the average width of the strip;

b_0 为条带的平均宽度;

D_0 is the external diameter of the tube;

D_0 为管材的外径;

a_0 is the thickness of the tube wall.

a_0 为管壁厚度。

The simplified Formula (E.3) can be used for longitudinal test pieces where the ratio between width and external tube diameter falls below set limits:

当宽度与管材外径之比低于设定限值时，纵向试件可使用简化公式(E.3):

$$\begin{aligned} S_o &= a_o b_o \left[1 + \frac{b_o^2}{6D_o(D_o - 2a_o)} \right] & \text{if } \frac{b_o}{D_o} < 0,25 \\ S_o &= a_o b_o & \text{if } \frac{b_o}{D_o} < 0,10 \end{aligned} \quad (E.3)$$

For length of tube, the original cross-sectional area, S_o , shall be calculated from Formula (E.4):

对于管材长度，原始横截面积 S_o 应根据公式(E.4)计算:

$$S_o = \pi a_o (D_o - a_o) \quad (E.4)$$

Annex F

附录 F

(informative)

(资料性)

Estimation of the crosshead separation rate in consideration of the stiffness (or compliance) of the testing equipment

考虑测试设备刚度(或柔度)的十字头分离速率估算

Formula (2) does not consider any elastic deformation of the testing equipment (frame, load cell, grips, etc.) during the application of force to the test piece. It is possible to estimate a compensation for the deflection of the testing equipment by using the stiffness of the test piece at the point of interest (e.g. $R_{p0.2}$). If the point of interest is beyond the elastic range (e.g. $R_{p0.2}$), the use of the stiffness of the test piece during the elastic portion of the stress strain curve will result in a grossly overestimated correction. The stiffness of the testing equipment shall also be known for the grip configuration and grip separation used. For some configurations, the effective stiffness of the testing equipment may increase substantially as the grips bite into the test piece during a test. It is imperative that the stiffness of the testing equipment be evaluated at the point of interest.

公式(2)未考虑在对试件施加力的过程中测试设备(框架、测力传感器、夹具等)的任何弹性变形。可以通过使用感兴趣点处试件的刚度(例如 $R_{p0.2}$)来估算测试设备挠度的补偿值。如果感兴趣点超出弹性范围(例如 $R_{p0.2}$)，在应力应变曲线的弹性

部分使用试件的刚度将导致校正值得严重高估。对于所使用的夹具配置和夹具间距，测试设备的刚度也应已知。对于某些配置，在测试过程中，随着夹具咬入试件，测试设备的有效刚度可能会大幅增加。必须在感兴趣点处评估测试设备的刚度。

If desired, use the following procedure to calculate a crosshead separation rate that is compensated for the deflection of the testing equipment during a test, using the stiffness of the testing equipment at the point of interest and the slope of the stress-strain curve at the point of interest. It is recommended to check the resulting strain rate at the point of interest while doing a test to ensure that the calculation has been done appropriately.

如果需要，可使用以下步骤计算十字头分离速率，该速率考虑了测试过程中测试设备的挠度补偿，使用感兴趣点处测试设备的刚度和感兴趣点处应力应变曲线的斜率。建议在进行测试时检查感兴趣点处的应变率结果，以确保计算正确。

The estimated strain rate, in reciprocal seconds, during a test at the point of interest is given by Formula (F.1) (see Reference [39]):

在感兴趣点处测试期间，以每秒倒数表示的估算应变率由公式(F.1)给出(见参考文献[39]):

$$\dot{\epsilon}_m = \frac{v_c}{\frac{m \cdot S_0}{C_M} + L_c} \quad (F.1)$$

where

其中

is the crosshead separation rate, in millimetres per second;

是十字头分离速率，单位为毫米每秒；

is the slope, in megapascals, of the stress-percentage extension curve at a given moment of the test (e.g. around the point of interest such as $R_{p0.2}$);

是在测试给定时刻(例如在感兴趣点如 $R_{p0.2}$ 附近)应力-伸长百分比曲线的斜率，单位为兆帕；

S_0 is the original cross-section area, in square millimetres;

S_0 是原始横截面积，单位为平方毫米；

C_M is the stiffness, in newtons per millimetre, of the testing equipment (around the point of interest such as $R_{p0.2}$, if stiffness is not linear, e.g. when using wedge grips);

C_M 是测试设备(在感兴趣点如 $R_{p0.2}$ 附近，如果刚度不是线性的，例如使用楔形夹具时)的刚度，单位为牛顿每毫米；

L_c is the parallel length, in millimetres, of the test piece.

L_c 是试件的平行长度，单位为毫米。

NOTE The values of m and C_M derived from the linear portion of the stress/strain curve cannot be used.

注:不能使用从应力/应变曲线线性部分得出的 m 和 C_M 值。

Formula (2) does not compensate for the effects of compliance (see 10.3.2.1). When controlling the test by crosshead displacement, a better approximation of the required strain rate can be achieved by using the crosshead separation rate derived from Formula (F.2) (see Reference [40]):

公式(2)未补偿柔度的影响(见 10.3.2.1)。当通过十字头位移控制测试时，使用从公式(F.2)得出的十字头分离速率(见参考文献[40])可以更好地近似所需的应变率:

$$v_c = \dot{e}_m \left(\frac{m \cdot S_o}{C_M} + L_c \right) \quad (F.2)$$

For using Formula (E.1) or (E.2), it is necessary to know the stiffness C_M of the complete used testing equipment (testing rig, load cell, clamping system for test pieces to be tested). The following procedure, firstly described in Reference [53], provides correct values for the stiffness C_M .

为了使用公式(E.1)或(E.2)，有必要知道所使用的完整测试设备(测试装置、测力传感器、待测试件的夹紧系统)的刚度 C_M 。以下步骤首次在参考文献[53]中描述，可提供刚度 C_M 的正确值。

A test piece of the same geometry and similar properties to the material to be subsequently tested is tested using a slow known constant crosshead separation rate. Then the following parameters have to be determined:

使用已知的缓慢恒定十字头分离速率，对与后续要测试的材料具有相同几何形状和相似特性的试件进行测试。然后必须确定以下参数:

- from the stress/strain diagram, the slope m around the point of interest;
- 从应力/应变图中，感兴趣点周围的斜率 m ；
- from the percentage extension/time curve, the resulting strain rate around the point of interest.
- 从百分比伸长率/时间曲线得出感兴趣点周围的应变率。

The stiffness can now be calculated using Formula (F.3) [conversion of Formula (F.1) or (F.2) according to C_M].

现在可以使用公式(F.3)[根据 C_M 对公式(F.1)或(F.2)进行转换]来计算刚度。

$$C_M = \frac{m \cdot S_o}{\frac{v_c}{\dot{\epsilon}_m} - L_c} \quad (F.3)$$

This procedure should only be used for materials with no discontinuous yielding behaviour in the relevant range. For testing materials which exhibits discontinuous or serrated yielding, the knowledge of the stiffness is not necessary because the estimated strain rate over the parallel length, $\dot{\epsilon}_L$ and the simplified Formula (2) (see 10.3.2.1) instead of Formula (F.2) should be used for the calculation of the crosshead separation rate v_c .

本程序仅适用于在相关范围内无间断屈服行为的材料。对于测试表现出间断或锯齿状屈服的材料，由于不需要了解刚度，因为应使用平行长度上的估计应变率 $\dot{\epsilon}_L$ 和简化公式(2)(见 10.3.2.1)而非公式(F.2)来计算十字头分离速率 v_c 。

Annex G

附录 G

(normative)

(规范性)

Determination of the modulus of elasticity of metallic materials using a uniaxial tensile test

使用单轴拉伸试验测定金属材料的弹性模量

G.1 Background

G.1 背景

Although ISO 6892-1 requires the generation of a straight line with a given offset parallel to the linear region of the stress-strain curve in order to determine the specified proof strength, R_p , of the material being tested, most users usually assume that the slope of the linear elastic region of the stress-strain curve corresponds to the modulus of elasticity of the material being tested since the modulus of elasticity, E , is given by the relationship $E = \text{stress/strain}$. However, in general, the Class 1 extensometer required for the tensile test is not sufficiently accurate for measuring the very small strains in the elastic region with sufficient precision to give modulus values with an acceptable level of uncertainty.

尽管 ISO 6892-1 要求生成一条与被测试材料应力-应变曲线的线性区域平行且具有给定偏移量的直线，以便确定被测试材料的规定比例极限强度(R_p)，但大多数用户通常认为应力-应变曲线线性弹性区域的斜率对应于被测试材料的弹性模量，因为弹性模量(E)由应力/应变关系($E =$)给出。然而，一般来说，拉伸试验所需的 1 级引伸计对于精确测量弹性区域中非常小的应变以给出具有可接受不确定度水平的模量值而言，精度不够。

It is not required to use this annex to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

在确定规定强度时，无需使用本附录来确定应力-伸长率曲线弹性部分的斜率。

An additional description of the determination of the modulus of elasticity by tensile testing is given in ASTM E 111 [52]. For information, see also SEP 1235 [43].

ASTM E 111 [52]中给出了通过拉伸试验测定弹性模量的附加说明。如需了解更多信息，另见 SEP 1235 [43]。

G.2 General

G.2 总则

This annex contains additional requirements for the determination of the modulus of elasticity using a uniaxial tensile test. This test method is limited to materials which meet the following criteria:

本附录包含使用单轴拉伸试验测定弹性模量的附加要求。本试验方法仅限于符合以下标准的材料：

- negligible creep effects of the material in the evaluation range;
- 在评估范围内材料的蠕变效应可忽略不计；
- sufficient straight line in the elastic range of the material in the evaluation range.
- 在评估范围内材料弹性范围内有足够的直线。

These requirements are related to the design of the testing equipment, the test piece and the evaluation of the test.

这些要求与测试设备、试件的设计以及测试评估有关。

The modulus of elasticity is a characteristic material property and is used for the calculation of the elasticity of products and components conforming to Hooke's Law.

弹性模量是材料的一种特性，用于计算符合胡克定律的产品和部件的弹性。

NOTE Typically, this test is performed as a separate test from the tensile test because of the limitation of the extensometer displacement.

注意:通常，由于引伸计位移的限制，此测试作为与拉伸测试分开的测试进行。

G.3 Testing equipment

G.3 测试设备

G.3.1 Accuracy of the testing equipment

G.3.1 测试设备的精度

G.3.1.1 Force-measuring device

G.3.1.1 测力装置

The force-measuring system of the testing machine shall be in accordance with ISO 7500-1, class 1, in the relevant range.

试验机的测力系统在相关范围内应符合 ISO 7500-1 标准的 1 级要求。

G.3.1.2 Extensometer system

G.3.1.2 引伸计系统

The extensometer system shall be in accordance with ISO 9513, class 0,5, in the relevant range.

引伸计系统在相关范围内应符合 ISO 9513 标准 0.5 级。

The strain shall be measured on opposite sides of the test piece.

应变应在试件的相对两侧进行测量。

The use of a large extensometer gauge length (e.g. ≥ 50 mm) is recommended.

建议使用较大的引伸计标距长度(例如 $\geq 50 \text{ mm}$)。

G.3.1.3 Resolution of the testing system

G.3.1.3 测试系统的分辨率

The resolution of the testing system shall be sufficient for obtaining at least 50 different discrete measured values in the evaluation range.

测试系统的分辨率应足以在评估范围内获得至少 50 个不同的离散测量值。

G.3.1.4 Measuring devices for the determination of the relevant test piece dimensions

G.3.1.4 用于确定相关试件尺寸的测量装置

All measuring devices used for the determination of the original cross-sectional area shall be calibrated to the appropriate standards with traceability to a national measurement system. The measuring device shall be able to guarantee an accuracy of the measured data of better than $\pm 0,5 \%$ of the measured value.

所有用于测定原始横截面积的测量设备均应按照适当标准进行校准，且可追溯至国家测量系统。测量设备应能够保证所测数据的准确度优于测量值的 $\pm 0.5\%$ 。

G.3.2 Method of gripping and alignment

G.3.2 抓取与对齐方法

The method of gripping and the alignment are important for the determination of the modulus of elasticity. For requirements regarding the method of gripping, see 10.2, and for further information, see ASTM E1012. Additional helpful information may be in ISO 23788.

夹持方法和对中对于弹性模量的测定很重要。关于夹持方法的要求，见 10.2，如需更多信息，见 ASTM E1012。ISO 23788 中可能有更多有用信息。

It is recommended to use mechanical devices (e.g. stoppers) to position the test piece so that good alignment is achieved.

建议使用机械装置(如挡块)来定位试样，以实现良好的对中。

G.4 Test pieces

G.4 试样

G.4.1 General

G.4.1 一般规定

The test pieces shall be straight.

试样应是直的。

NOTE Bent or twisted test pieces cannot be tested according to this annex.

注:弯曲或扭曲的试样不能按照本附录进行试验。

The test piece surface shall be in such a condition that it does not influence the test result.

试样表面应处于不影响试验结果的状态。

Where residual stresses are present in the sample, as a result of either prior processing or sample preparation, the modulus values determined are sometimes not representative of the base material.

如果由于先前的加工或试样制备, 试样中存在残余应力, 则所测定的模量值有时不能代表基体材料。

G.4.2 Determination of original cross-sectional area

G.4.2 原始横截面积的测定

For the determination of the original cross-sectional area, see Clause 7. In addition to the requirements in Clause 7, a minimum of three measurements for each dimension shall be performed. The original cross-sectional area, S_0 , is the average cross-sectional area and shall be calculated from the measurements of the appropriate dimensions. The original cross-sectional area shall be determined with an accuracy of $\pm 0,5\%$ or better.

原始横截面积的测定见第 7 条。除第 7 条的要求外, 每个尺寸至少应进行三次测量。原始横截面积 S_0 是平均横截面积, 应根据适当尺寸的测量值计算得出。原始横截面积的测定精度应为 $\pm 0,5\%$ 或更高。

G.5 Procedure

G.5 试验步骤

G.5.1 General

G.5.1 一般规定

If the stress-strain curve up to R_{eH} or $R_{p0.2}$ is not known, a pre-test in advance of the measurement of the modulus of elasticity shall be performed.

如果直至 R_{eH} 或 $R_{p0.2}$ 的应力-应变曲线未知，则在测定弹性模量之前应预先进行一次预试验。

G.5.2 Setting the force zero point

G.5.2 力零点的设定

The setting of the force zero point shall be carried out in accordance with 10.1.

力零点的设定应按照 10.1 进行。

G.5.3 Testing conditions

G.5.3 试验条件

G.5.3.1 Testing rate

G.5.3.1 试验速率

Compared to the other properties determined within the tensile test, the modulus of elasticity is less sensitive to the testing rate. The testing rate should be according to Method A Range 1. Other testing rates including the use of Method B are permitted.

与拉伸试验中测定的其他性能相比，弹性模量对试验速率不太敏感。试验速率应符合方法 A 范围 1。也允许使用包括方法 B 在内的其他试验速率。

The testing rate may be low to achieve the required number of data points for the analysis.

试验速率可能较低，以便获得分析所需的数据点数。

A constant crosshead separation rate may be used to avoid any discontinuities.

可采用恒定的十字头分离速率，以避免出现任何不连续情况。

G.5.3.2 Data sampling frequency

G.5.3.2 数据采集频率

The data sampling frequency shall be chosen in such a way that a minimum of 50 measured values is obtained in the relevant range (R_1, R_2).

数据采集频率的选择应确保在相关范围 (R_1, R_2) 内至少获得 50 个测量值。

The minimum data sampling frequency can be calculated by Formula (G.1):

最小数据采集频率可通过公式(G.1)计算:

$$f = \frac{N \cdot E \cdot \dot{\epsilon}}{R_2 - R_1} \quad (\text{G.1})$$

where N is the number of measured values in the relevant range.

其中 N 是相关范围内的测量值数量。

For steel with $R_1 = 10\text{MPa}$ and $R_2 = 50\text{MPa}$ and a testing rate of $0,00007 \text{ s}^{-1}$, the data sampling frequency shall be greater than 18 Hz.

对于具有 $R_1 = 10\text{MPa}$ 和 $R_2 = 50\text{MPa}$ 且试验速率为 $0,00007 \text{ s}^{-1}$ 的钢材，数据采集频率应大于 18 Hz。

G.5.3.3 Testing procedure

G.5.3.3 试验程序

If the test piece will be used more than one time for the modulus determination, the applied load shall not be greater than a value corresponding to 50% of the expected R_{eH} or $R_{p0,2}$.

如果试验件将多次用于模量测定，则施加的载荷不应大于对应于预期 R_{eH} 或 $R_{p0,2}$ 的 50% 的数值。

Otherwise, it is recommended to perform the test up to a point where plastic deformation can be observed.

否则，建议进行试验直至观察到塑性变形。

G.6 Evaluation

G.6 评估

G.6.1 Averaging the extensometry signals

G.6.1 引伸计信号平均

The average strain, necessary for the calculation in G.6.2, is calculated for each stress value by averaging the strain from the opposite sides of the test piece.

在 G.6.2 计算中所需的平均应变，是通过对试验件相对两侧的应变进行平均，为每个应力值计算得出的。

Strain data from each side of the test piece may be displayed and differences in the slope of the two curves may be reduced by optimizing the testing equipment (reducing of bending). For further information, see ASTM E 1012. Additional helpful information can be found in ISO 23788.

试验件每一侧的应变数据均可显示，并且通过优化试验设备(减少弯曲)，可减小两条曲线斜率的差异。更多信息，请参见 ASTM E 1012。在 ISO 23788 中可找到更多有用信息。

G.6.2 Calculation of the modulus of elasticity

G.6.2 弹性模量的计算

For evaluation of the recorded data, the following interactive method is recommended.

为评估记录的数据，建议采用以下交互式方法。

The method is based on a numerical determination of the line of best fit for the elastic range (least squares method) including a visual evaluation of the match between this line of best fit and the curve of actual measurement readings, followed

by recalculation with altered parameters, where appropriate. Therefore, it corresponds essentially to a manual analysis of an X-Y graph.

该方法基于对弹性范围的最佳拟合线进行数值确定(最小二乘法), 包括对该最佳拟合线与实际测量读数曲线之间的匹配进行视觉评估, 必要时使用更改后的参数重新计算。因此, 它本质上相当于对 X - Y 图进行手动分析。

The use of this method depends on the availability of suitable computer software.

该方法的使用取决于是否有合适的计算机软件。

A linear regression of stress over strain (G.4) shall be carried out between a lower stress value R_1 and an upper stress value R_2 (alternatively, strain values e_1 and e_2 may be used):

应在较低应力值 R_1 和较高应力值 R_2 之间进行应力对应变的线性回归(G.4)(或者, 也可使用应变值 e_1 和 e_2):

$$R = \frac{E \cdot e}{100\%} + b \quad (\text{G.2})$$

where

其中

R is the stress in megapascals;

R 是以兆帕为单位的应力;

E is the modulus of elasticity in megapascals;

E 是弹性模量, 单位为兆帕;

e is the percentage extension in percent;

e 是以百分比为单位的伸长率;

b is the stress offset in megapascals.

b 是以兆帕为单位的应力偏移量。

The straight line determined in this way shall be drawn into the stress-strain diagram, whereas the initial part of this diagram is magnified for this purpose. The match between the straight line and the curve shall be evaluated visually. It can be useful to consider the coefficient of determination R^2 , which should be close to 1 (>0.9995), whereby the number of considered data points should be at least 50.

以这种方式确定的直线应绘制在应力 - 应变图中, 为此该图的起始部分应放大。应通过视觉评估直线与曲线之间的匹配情况。考虑决定系数 R^2 可能会有所帮助, 其应接近 1(>0.9995), 其中所考虑的数据点数量应至少为 50 个。

Another helpful tool is the calculation of the relative standard deviation. The relative standard deviation takes into account the coefficient of determination R^2 and the number of considered data points among other statistical data. It should be less than 1 %.

另一个有用的工具是相对标准偏差计算。相对标准偏差除其他统计数据外，还考虑决定系数 R^2 和所考虑的数据点数量。其应小于 1%。

By shifting the lower or upper values and re-calculating the formula accordingly, the line of best fit (i.e. the modulus of elasticity) can be adapted to the curve.

通过移动较低或较高值并相应地重新计算公式，可以使最佳拟合线(即弹性模量)与曲线相适配。

The following values are recommended as starting points for the regression calculation:

建议将以下值作为回归计算的起始点:

- lower stress value R_1 : $\approx 10\%$ of R_{eH} or $R_{p0.2}$;
- 较低应力值 R_1 : $\approx 10\%$ 为 R_{eH} 或 $R_{p0.2}$;
 - upper stress value R_2 : $\approx 40\%$ of R_{eH} or $R_{p0.2}$.
- 较高应力值 R_2 : $\approx 40\%$ 为 R_{eH} 或 $R_{p0.2}$ 。

Additionally, the strain offset can be calculated according to Formula (G.3):

此外，应变偏移可根据公式(G.3)计算:

$$x_{(y=0)} = \frac{-b}{E} \quad (G.3)$$

Under optimal testing conditions, the chosen default values will not have a great influence on the result of the calculation. Example: if the material fulfils the general conditions described in G.2 and the determined default values R_1 and R_2 are 10% and 40% of R_{eH} or $R_{p0.2}$, respectively, a re-calculation of the formula by using default values inside the determined interval (e.g. 10% to 20%, 20% to 30%, 30% to 40% of R_{eH} or $R_{p0.2}$, respectively) will not influence the result significantly.

在最佳测试条件下，所选默认值对计算结果影响不大。例如:如果材料符合 G.2 中所述的一般条件，且确定的默认值 R_1 和 R_2 分别为 R_{eH} 的 10% 和 40% 或 $R_{p0.2}$ ，则在确定的区间内使用默认值(例如分别为 10%至 20%、20%至 30%、30%至 R_{eH} 的 40% 或 $R_{p0.2}$)重新计算公式不会对结果产生显著影响。

In cases where the material exhibits no straight elastic line, e.g. cast iron, or the data for the regression is not of sufficient quality, i.e. $R^2 < 0,999\,5$, the modulus of elasticity should not be determined.

如果材料没有直线弹性线，例如铸铁，或者回归数据质量不足，即 $R^2 < 0,9995$ ，则不应确定弹性模量。

It is recommended to perform regular checks on the repeatability of the results using suitable reference test pieces in the configuration used for testing.

建议使用测试配置中的合适参考试件对结果的可重复性进行定期检查。

Suitable reference test pieces can be manufactured in-house and should have the same geometry as the test pieces.

合适的参考试件可以在内部制造，并且应与测试试件具有相同的几何形状。

Further mathematical approaches and computer analysis methods are available for the evaluation of the modulus of elasticity.

还有其他数学方法和计算机分析方法可用于评估弹性模量。

G.7 Measurement uncertainty

G.7 测量不确定度

G.7.1 General

G.7.1 一般情况

The estimation of the measurement uncertainty for a determined modulus of elasticity can be done according to CWA 15261-2:2005, A.5 [9] or according to Annex K.

对于确定的弹性模量，测量不确定度的估计可根据 CWA 15261-2:2005, A.5 [9]或根据附录 K 进行。

NOTE The estimation of the measurement uncertainty according to CWA 15261-2 is based on absolute values. This results in different estimations of the respective single uncertainty budgets, if e.g. the test piece dimensions or the extensometer gauge length differ. The estimation of the measurement uncertainty according to Annex K is based on relative estimations. Therefore, the relative estimations normally will not change. Exception is the relative measurement uncertainty budget for the strain measurement. Because of the small extensions during the test in the elastic part, the absolute uncertainty of the strain measurement is relevant for the uncertainty contribution (according to ISO 9513).

注:根据 CWA 15261-2 对测量不确定度的估计基于绝对值。如果例如试件尺寸或引伸计标距长度不同,这会导致各个单项不确定度预算的估计不同。根据附录 K 对测量不确定度的估计基于相对估计。因此,相对估计通常不会改变。应变测量的相对测量不确定度预算除外。由于弹性部分测试期间的伸长量较小,应变测量的绝对不确定度与不确定度贡献相关(根据 ISO 9513)。

G.7.2 Estimation of the measurement uncertainty according to CWA 15261-2

G.7.2 根据 CWA 15261-2 估计测量不确定度

G.7.2.1 General

G.7.2.1 一般情况

NOTE In CWA 15261-2, the symbol L_0 is used for the gauge length and m_E for the slope of the elastic part of the force-extension curve. For conformation with this document and to prevent confusion in the following (differing from CWA), the symbol L_e is used for the extensometer gauge length and S_E for the slope of the elastic part of the force-extension curve.

注:在 CWA 15261-2 中,符号 L_0 用于标距长度, m_E 用于力-伸长曲线弹性部分的斜率。为了与本文档一致并防止后续混淆(与 CWA 不同),符号 L_e 用于引伸计标距长度, S_E 用于力-伸长曲线弹性部分的斜率。

The measurement uncertainty according to CWA 15261-2 is given by Formula (G.4):

根据 CWA 15261-2 的测量不确定度由公式(G.4)给出:

$$u_c(E) = \sqrt{\left(\frac{L_e}{S_0}\right)^2 \cdot u^2(S_E) + \left(\frac{S_E}{S_0}\right)^2 \cdot u^2(L_e) + \left(-\frac{S_E L_e}{S_0^2}\right)^2 \cdot u^2(S_0)} \quad (G.4)$$

where

其中

L_e is the extensometer gauge length;

L_e 是引伸计标距长度;

S_0 is the original cross-sectional area;

S_0 是原始横截面积;

S_E is the slope of the force-extension curve;

S_E 是力-伸长曲线的斜率;

$u(S_E)$ is the uncertainty of slope of the force-extension curve;

$u(S_E)$ 是力-伸长曲线斜率的不确定度;

$u(L_e)$ is the uncertainty of extensometer gauge length;

$u(L_e)$ 是引伸计标距的不确定度;

$u(S_0)$ is the uncertainty of original cross-sectional area.

$u(S_0)$ 是原始横截面积的不确定度。

G.7.2.2 Example for the calculation of the measurement uncertainty

G.7.2.2 测量不确定度计算示例

Table G. 1 shows the results of an example for the measurement uncertainty according to CWA 15261-2 for a measured modulus of elasticity of 186,7GPa^[54] based on the following data:

表 G.1 给出了根据 CWA 15261-2 对基于以下数据测得的 186,7GPa^[54] 的弹性模量进行测量不确定度计算的一个示例结果:

L_e : 50 mm

S_0 : 78,5 mm²

S_E : 293,07kN/mm

$u(L_e)$: 0,144 mm

$u(S_0)$: 0,785 mm²

$u(S_E)$: 0,064 kN/mm

$$\begin{aligned} u_c(E) &= \sqrt{0.637^2 \cdot 0.064^2 + 3.733^2 \cdot 0.144^2 + (-2,378)^2 \cdot 0.785^2} \\ &= 1,9\text{GPa} \quad (\text{G.5}) \end{aligned}$$

Table G.1 — Uncertainty contribution, example 1 according to CWA 15261-2

表 G.1 — 根据 CWA 15261-2 的不确定度贡献, 示例 1

Parameter	Sensitivity coefficients ^a	Uncertainty contribution ^a
$\frac{L_e}{S_0}$	$0,637 \text{ mm}^{-1}$	
$u(S_E)$		$0,064 \frac{\text{kN}}{\text{mm}}$
$\frac{S_E}{S_0}$	$3,733 \frac{\text{kN}}{\text{mm}^3}$	
$u(L_e)$		$0,144 \text{ mm}$
$-\frac{S_E L_e}{S_p^2}$	$-2,378 \frac{\text{kN}}{\text{mm}^4}$	
$u(S_0)$		$0,785 \text{ mm}^2$
$u_c(E)^b$		$1,9 \frac{\text{kN}}{\text{mm}^2}$
a Values are given for information only. b $u_c(E)$ is calculated according to Formula (G.5).		
参数	灵敏度系数 ^a	不确定度贡献 ^a
$\frac{L_e}{S_0}$	$0,637 \text{ mm}^{-1}$	
$u(S_E)$		$0,064 \frac{\text{kN}}{\text{mm}}$
$\frac{S_E}{S_0}$	$3,733 \frac{\text{kN}}{\text{mm}^3}$	
$u(L_e)$		0.144 毫米
$-\frac{S_E L_e}{S_p^2}$	$-2,378 \frac{\text{kN}}{\text{mm}^4}$	
$u(S_0)$		$0,785 \text{ mm}^2$
$u_c(E)^b$		$1,9 \frac{\text{kN}}{\text{mm}^2}$
a 仅提供参考值。b $u_c(E)$ 根据公式 (G.5) 计算得出。		

For a 95% level of confidence, the combined uncertainty shall be multiplied by a coverage factor, $k = 2$ [see Formula (G.6)].

对于 95% 的置信水平，合成不确定度应乘以包含因子 $k = 2$ [见公式(G.6)]。

$$U(E) = k \cdot u_c(E) = 2 \cdot 1,9 \text{ GPa} = 3,8 \text{ GPa} \quad (\text{G.6})$$

This is 2,0 % based on the modulus of elasticity of 186,7 GPa.

基于 186.7 吉帕的弹性模量，此值为 2.0%。

The result of the test for the modulus of elasticity is: $186,7\text{GPa} \pm 3,8\text{GPa}$ ($k = 2,95\%$ confidence level) .

弹性模量测试结果为: $186,7\text{GPa} \pm 3,8\text{GPa}$ ($k = 2,95\%$ confidence level) 。

That means that, with a confidence level of 95% , the true value for the modulus of elasticity is in the range between 182,9 GPa and 190,5 GPa.

这意味着，在置信水平为 95% 时，弹性模量的真值在 182.9 吉帕至 190.5 吉帕之间。

G.7.3 Estimation of the measurement uncertainty according to Annex K

G.7.3 根据附录 K 估算测量不确定度

Table G.2 indicates the uncertainty contribution that should be considered for the modulus of elasticity according to Annex K.

表 G.2 列出了根据附录 K 应考虑弹性模量不确定度贡献。

Table G.2 - Uncertainty contribution, example 2 according to Annex K

表 G.2 - 根据附录 K 的不确定度贡献，示例 2

- Values are given for information only. b S_m consists of S_x and S_y , therefore S_x and S_y should be considered.
- 给出的值仅供参考。b S_m 由 S_x 和 S_y 组成，因此应考虑 S_x 和 S_y 。

Parameter	Uncertainty contribution ^a %
Standard deviation of slope S_{mfrell}	0,2
Standard deviation of X-values of the X-Y graph, $S_x^{b,c}$	3
Standard deviation of Y-values of the X-Y graph, S_y	1
Extensometer gauge length, L_e	0,5
Original cross-sectional area, S_o	1
- Values are given for information only.	
参数	不确定度贡献 ^a %
斜率的标准偏差 S_{mfrell}	0,2
X-Y 图中 X 值的标准偏差, $S_x^{b,c}$	3
X-Y 图中 Y 值的标准偏差, S_y	1

引伸计标距长度, L_e	0,5
原始横截面积, S_o	1
- 所提供的值仅用于参考。	

- Based on the small extensions measured in the test, the absolute value (1,5 μm of a class 0,5 extensometer) has to be used. Example: $\Delta R = 200\text{MPa}$, $E = 200\text{GPa}$, $L_e = 50\text{ mm}$ results in an extension of 0,05 mm . By using the bias error of 1,5 μm (absolute value of an 0,5 class extensometer), the uncertainty contribution is 3%.
- 根据测试中测得的微小伸长量, 必须使用绝对值(0.5 级引伸计为 1.5 μm)。示例: $\Delta R = 200\text{MPa}$, $E = 200\text{GPa}$, $L_e = 50\text{ mm}$ 得出的伸长量为 0,05 mm 。使用 1,5 μm 的偏差误差(0.5 级引伸计的绝对值), 不确定度贡献为 3%。

The combined uncertainty for the modulus of elasticity, expressed as a percentage, is given by Formula (G.7).

弹性模量的合成不确定度, 以百分比表示, 由公式(G.7)给出。

$$u_c(E) = \sqrt{\left(\frac{0,2}{\sqrt{3}}\right)^2 + \left(\frac{3}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{0,5}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2} = 1,9\% \quad (\text{G.7})$$

For a 95 % level of confidence, the combined uncertainty shall be multiplied by a coverage function, $k = 2$ [see Formula (G.8)].

对于 95%的置信水平, 合成不确定度应乘以一个覆盖因子, $k = 2$ [见公式(G.8)]。

$$U(E) = k \cdot u_c(E) = 2 \cdot 1,9\% = 3,8\% \quad (\text{G.8})$$

The result of the test for the modulus of elasticity is: (186,7 $\pm$ 7,1) GPa ($k = 2,95\%$ confidence level).

弹性模量测试的结果是: (186,7 $\pm$ 7,1) GPa ($k = 2,95\%$ 置信水平)。

This means that, with a confidence level of 95% , the true value for the modulus of elasticity is in the range between 179,6 GPa and 193,8 GPa.

这意味着, 在 95% 的置信水平下, 弹性模量的真实值在 179.6 GPa 至 193.8 GPa 之间。

G.7.4 Proficiency test

G.7.4 能力验证试验

A proficiency test "Young's Modulus" was performed and the measurement uncertainty for all participants was determined. An measurement uncertainty for the determination of the modulus of elasticity between 1,2 % and 5 % (at 95 % confidence level) is appropriate ^[54].

进行了一项“杨氏模量”能力验证试验，并确定了所有参与者的测量不确定度。对于弹性模量的测定，1.2%至5%(95%置信水平)的测量不确定度是合适的^[54]。

G.8 Test report

G.8 试验报告

The test report shall contain the information required in Clause 22 a) to f). Furthermore, the following information shall be included:

试验报告应包含第 22 条 a)至 f)要求的信息。此外，还应包括以下信息：

a) type of extensometer system;

a)引伸计系统的类型；

b) default stress values R_1 and R_2 (in MPa) or the default strain values e_1 and e_2 (in %), respectively;

b)默认应力值 R_1 和 R_2 (单位为 MPa)或默认应变值 e_1 和 e_2 (单位为%)；

c) number of measured values in the evaluation range (between R_1 and R_2 or e_1 and e_2);

c)评估范围内的测量值数量(在 R_1 和 R_2 之间或 e_1 和 e_2 之间)；

d) modulus of elasticity E (in GPa), which should be rounded to the nearest 0,1 GPa according to ISO 80000-1;

d)弹性模量 E (单位为 GPa)，应根据 ISO 80000-1 四舍五入到最接近的 0.1 GPa；

e) measurement uncertainty including level of confidence (in GPa) and the method of determination (CWA 15261-2:2005, A.5 or Table G.2);

e)测量不确定度，包括置信水平(单位为 GPa)和确定方法(CWA 15261-2:2005, A.5 或表 G.2)；

f) coefficient of determination R^2 of the best fit of the straight line or standard deviation S_m (in GPa) or relative standard deviation $S_{m(\text{rel})}$ (in %).

f) 直线最佳拟合的决定系数 R^2 或标准偏差 S_m (单位为 GPa) 或相对标准偏差 $S_{m(\text{rel})}$ (单位为%)。

G.9 Additional considerations

G.9 其他注意事项

In general, it is difficult to determine reliable values of modulus in the tensile test unless special high resolution averaging extensometer systems are employed, and such devices are not generally suitable for covering the full range of the tensile test. If a single sided extensometer or clip gauge is employed, then any slight misalignment of the test piece can result in large errors of the apparent modulus measurement.

一般来说，在拉伸试验中很难确定模量的可靠值，除非使用特殊的高分辨率平均引伸计系统，而这种设备通常并不适合覆盖拉伸试验的整个范围。如果使用单侧引伸计或夹式引伸计，那么试件的任何轻微不对中都可能导致表观模量测量出现较大误差。

G.10 Other methods for determining modulus

G.10 确定模量的其他方法

The tensile test is not the best method for determining reliable values of modulus of elasticity, and other alternative methods, e.g. impulse excitation or ultrasonics, are preferable. More information can be found in References [17] and [44] to [46].

拉伸试验并非确定弹性模量可靠值的最佳方法，其他替代方法，例如脉冲激励或超声波法，更为可取。更多信息可在参考文献[17]以及[44]至[46]中找到。

G.11 Uncertainty and reproducibility

G.11 不确定度和再现性

Full uncertainty budgets are not included here but procedures for estimating uncertainty based on the GUM^[4] associated with modulus measurements have been

developed as part of the European UNCERT project, both for tensile testing[42] and for dynamic measurements[48].

这里未包含完整的不确定度预算，但作为欧洲 UNCERT 项目的一部分，已经开发了基于与模量测量相关的 GUM^[4] 来估计不确定度的程序，适用于拉伸试验[42]和动态测量[48]。

Reproducibility of modulus measurements based on 2 times the standard deviation (s) from a series of tensile test inter-comparison exercises, collated as part of the TENSTAND Project, are summarized in Table G.3 [45].

基于一系列拉伸试验比对练习中两倍标准偏差(s)的模量测量再现性，作为 TENSTAND 项目的一部分进行了整理，总结在表 G.3 [45]中。

Table G.3 - Overview of round robin tests: modulus of elasticity or slope of the elastic line, respectively

表 G.3 - 循环试验概述:分别为弹性模量或弹性线斜率

Reference	Authors	Year	Material	Reproducibility ($\pm 2s$) %
Testing Materials of Construction	Unwin[50]	1910	Mild steel	2
VAMAS	Lord, Roebuck and Orkney[51]	1995	SiC/Al MMC	6
BCR Tensile Reference Material CRM 661	Ingelbrecht and Loveday[29]	2000	Nimonic 75	12
TENSTAND WP3 Modulus Measurement	Lord, Rides and Loveday[49]	2005	Various	5-25
TENSTAND WP2 ASCII Data Files	Lord, Loveday, Rides and McEnteggart [22]	2005	Various - ASCII datafiles	1-6
参考文献	作者	Year	材料	再现性($\pm 2s$)%
建筑测试材料	昂温[50]	1910	低碳钢	2
国际计量局材料先进标准验证与评估计划	洛德、罗巴克和奥克内尔[51]	1995	碳化硅/铝基复合材料	6
BCR 拉伸标准物质 CRM 661	英格尔布雷希特和洛夫迪[29]	2000	尼莫尼克 75 合金	12
TENSTAND WP3 模量测量	洛德、赖兹和洛夫迪[49]	2005	各种	5-25

TENSTAND WP2 ASCII 数据文件	洛德、洛夫迪、赖 兹和麦肯泰加特 [22]	2005	各种-ASCII 数据文件	1-6
----------------------------	-----------------------------	------	------------------	-----

The majority of the results reported above were based on the criteria laid down in ISO 6892 or the equivalent earlier standards. It should also be considered that the aim of several tests is the determination of common tensile test properties (e.g. also the generation of ASCII data sets in TENSTAND WP2). So the typically single sided Class 1 extensometers with a limited accuracy in the elastic range were employed and the slope of the elastic part of the stress-percentage extension curve m_E was determined with the aim of evaluation of $R_{p0.2}$ and other properties and not to determine the intrinsic material property modulus of elasticity E . If double sided high resolution Class 0,5 extensometers are used as specified in this annex, the uncertainty of measurement should be less and the reproducibility much better.

上述报告的大多数结果是基于 ISO 6892 规定的标准或等效的早期标准。还应考虑到，一些测试的目的是确定常见的拉伸试验性能(例如，在 TENSTAND WP2 中生成 ASCII 数据集)。因此，使用了通常在弹性范围内精度有限的单面 1 级引伸计，并确定了应力-伸长率曲线弹性部分的斜率 m_E ，目的是评估 $R_{p0.2}$ 和其他性能，而不是确定材料的固有属性弹性模量 E 。如果按照本附录的规定使用双面高分辨率 0.5 级引伸计，则测量不确定度应更小，再现性应更好得多。

ISO 6892-1:2019(E)

ISO 6892-1:2019(英文版)

Annex H

附录 H

(informative)

(提供信息的)

Measuring the percentage elongation after fracture if the specified value is less than 5 %

如果规定值小于 5%，则测量断裂后伸长率百分比

Precautions should be taken when measuring the percentage elongation after fracture if the specified value is less than 5%.

如果规定值小于 5%，则在测量断裂后伸长率百分比时应采取预防措施。

One of the recommended methods is as follows.

推荐的方法之一如下。

Prior to the test, a very small mark should be made close to each end of the parallel length. Using a pair of needle-pointed dividers set at the gauge length, an arc is scribed with the mark as a centre. After fracture, the broken test piece should be placed in a fixture and axial compressive force applied, preferably by means of a screw, sufficient to firmly hold the pieces together during measurement. A second arc of the same radius should then be scribed from the original centre closest to fracture, and the distance between the two scratches measured by means of a measuring microscope or other suitable instrument. In order to render the fine scratches more easily visible, a suitable dye film may be applied to the test piece before testing.

试验前，应在平行长度的两端附近做出非常小的标记。使用一对设置为标距长度的针尖式两脚规，以标记为圆心划一道弧线。断裂后，应将断裂的试件放置在夹具中，并施加轴向压缩力，最好通过螺丝施加，该力应足以在测量过程中将试件牢固地固定在一起。然后应从最靠近断裂处的原始圆心处划出相同半径的第二条弧线，并使用测量显微镜或其他合适的仪器测量两条划痕之间的距离。为了使细微划痕更易于观察，可在试验前在试件上施加一层合适的染料薄膜。

Annex I

附件一

(informative)

(提供信息的)

Measurement of percentage elongation after fracture based on subdivision of the original gauge length

基于原始标距细分的断裂后伸长率测量

I. 1 To avoid having to reject test pieces where the position of the fracture does not comply with the conditions of 20.1, but where the complete necking occurs inside the gauge length, the following method may be used:

I. 1 为避免必须拒收那些断裂位置不符合 20.1 规定条件，但在标距长度内发生完全颈缩的试样，可采用以下方法：

a) before the test, subdivide the original gauge length, L_0 , into N equal lengths of 5 mm (recommended) to 10 mm ;

a) 在测试前，将原始标距长度 L_0 细分为 N 个长度相等的 5 mm (推荐)至 10 mm ；

b) after the test, use the symbol X to denote the gauge mark on the shorter part of the test piece and the symbol Y for the gauge mark on the longer part of the test piece which is at the same distance from the fracture as mark X.

b) 试验后，用符号 X 表示试件较短部分上的标距标记，用符号 Y 表示试件较长部分上与标记 X 距断裂处距离相同的标距标记。

I. 2 If n is the number of intervals between X and Y, the elongation after fracture is determined as follows.

I. 2 如果 n 是 X 和 Y 之间的间隔数，则断裂后的伸长率按以下方法确定。

a) If $N - n$ is an even number [see Figure I.1 a)], measure the distance between X and Y, l_{XY} , and the distance from Y to the graduation mark Z, l_{YZ} , located at $(N - n)/2$ intervals beyond Y.

a) 如果 $N - n$ 是偶数 [见图 I.1 a)], 测量 X 和 Y, l_{XY} 之间的距离，以及从 Y 到位于 Y 之外 $(N - n)/2$ 间隔处的刻度标记 Z, l_{YZ} 的距离。

Calculate the percentage elongation after fracture, A , using Formula (I.1):

使用公式(I.1)计算断裂后伸长率百分比， A ：

$$A = \frac{l_{XY} + 2l_{YZ} - L_0}{L_0} \cdot 100 \quad (I.1)$$

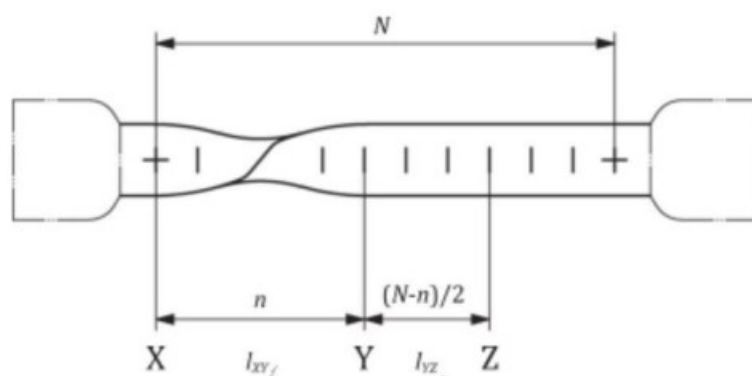
b) If $N - n$ is an odd number [see Figure I.1 b)], measure the distance between X and Y and the distance from Y to the graduation marks Z' and Z'', $l_{YZ'}$, and $l_{YZ''}$, located respectively at $(N - n - 1)/2$ and $(N - n + 1)/2$ intervals beyond Y.

b) 如果 $N - n$ 是奇数 [见图 I.1 b)], 测量 X 和 Y 之间的距离以及从 Y 到分别位于超出 Y 的 $(N - n - 1)/2$ 和 $(N - n + 1)/2$ 间隔处的刻度标记 Z'、Z''、 $l_{YZ'}$ 和 $l_{YZ''}$ 的距离。

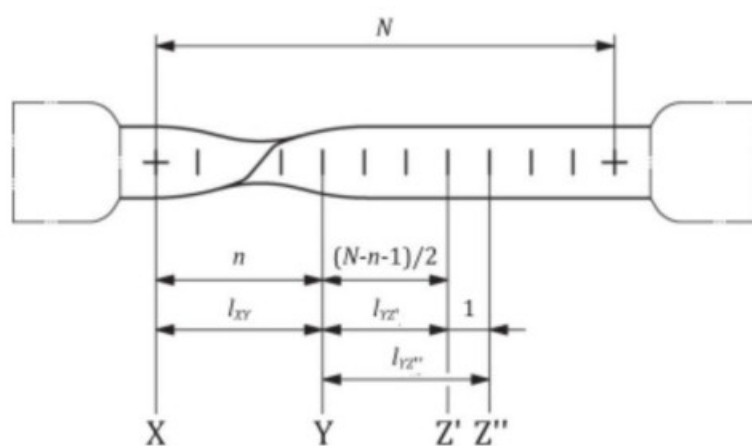
Calculate the percentage elongation after fracture using Formula (I.2):

使用公式(I.2)计算断裂后伸长率百分比：

$$A = \frac{l_{XY} + l_{YZ'} + l_{YZ''} - L_0}{L_0} \cdot 100 \quad (I.2)$$



a) $N - n$ is an even number



b) $N - n$ is an odd number

Key

键

n number of intervals between X and Y

n X 和 Y 之间的间隔数

N number of equal lengths

N 等长段数

X gauge mark on the shorter part of the test piece

X 试件较短部分上的标距标记

Y gauge mark on the longer part of the test piece

Y 试件较长部分上的标距标记

Z, Z', Z'' gauge marks

Z, Z', Z'' 标距标记

The shape of the test-piece heads is only given as a guide.

试件头部的形状仅作参考。

Figure 1.1 — Examples of measurement of percentage elongation after fracture

图 1.1 — 断裂后伸长率百分比测量示例

Annex J

附录 J

(informative)

(资料性)

Determination of the percentage plastic elongation without necking, A_{wn} , for long products such as bars, wire, and rods

对于棒材、线材和杆材等长产品，无缩颈塑性伸长率百分比 A_{wn} 的测定

This method is to be performed on the longer part of a broken tensile test piece.

此方法应在拉伸试验断裂试件的较长部分上进行。

Before the test, equidistant marks are made on the gauge length, the distance between two successive marks being equal to a fraction of the initial gauge length, L'_0 . The marking of the initial gauge length, L'_0 , should be accurate to within $\pm 0,5$ mm. The measurement of the final gauge length after fracture, L'_{10} , is made on the longest broken part of the test piece and should be accurate to within $\pm 0,5$ mm.

试验前，在标距长度上制作等距标记，两个连续标记之间的距离等于初始标距长度 L'_0 的一部分。初始标距长度 L'_0 的标记应精确到 $\pm 0,5$ mm 以内。断裂后最终标距长度 L'_{10} 的测量应在试件最长的断裂部分上进行，且应精确到 $\pm 0,5$ mm 以内。

In order for the measurement to be valid, the following two conditions should be met:

为使测量结果有效，应满足以下两个条件：

a) the limits of the measuring zone should be located at least $5d_0$ from the fracture and at least $2,5d_0$ from the grip;

- a) 测量区域的边界应距离断裂处至少 $5d_0$, 且距离夹具至少 $2,5d_0$;
- b) the measuring gauge length should be at least equal to the value specified in the product standard.
- b) 测量标距长度应至少等于产品标准中规定的值。

The percentage plastic elongation without necking is calculated by Formula (J.1):

无缩颈的塑性伸长率百分比按公式 (J.1) 计算:

$$A_{wn} = \frac{L'_u - L'_o}{L'_o} \cdot 100 \quad (J.1)$$

NOTE For many metallic materials, the maximum force occurs in the range where necking starts. This means that the values for A_g and A_{wn} for these materials are nearly equal. Large differences are found in highly cold deformed material such as double reduced tin plate or irradiated structural steel or tests performed at elevated temperatures.

注:对于许多金属材料,最大力出现在缩颈开始的范围内。这意味着这些材料的 A_g 和 A_{wn} 值几乎相等。在高冷加工材料(如二次冷轧镀锡板或辐照结构钢)或高温下进行的试验中会发现较大差异。

Annex K

附录 K

(informative)

(资料性)

Estimation of the uncertainty of measurement

测量不确定度的评估

K.1 General

K.1 总则

This annex gives guidance on how to estimate the uncertainty of the values determined in accordance with this document. It is not possible to give an absolute statement of uncertainty for this test method because there are both material independent and material dependent contributions to the uncertainty statement.

ISO/IEC Guide 98-3[4] is a comprehensive document of over 90 pages based upon rigorous statistical methods for the summation of uncertainties from various sources. Its complexity has provided the driving force for a number of organizations to produce simplified versions (see NIS 80^[1.5], NIS 3003^[16], and Reference [23]). These documents all give guidance on how to estimate uncertainty of measurement based upon an "uncertainty budget" concept. For detailed descriptions, see EN 10291[11] and Reference [24]. Additional information on the estimation of uncertainty is available in References [25] and [26]. The measurement uncertainty presented here does not describe the scatter resulting from the inhomogeneity of the material, e.g. from one batch, from the beginning and at the end of an extruded profile or a rolled coil, or of different positions within a casting. The uncertainty results from the scatter of the data obtained from different tests, different machines, or different laboratories taken from an ideal homogeneous material. In the following, the different influences are described and guidance for the determination of the uncertainties is given.

本附录给出了关于如何评估根据本文件确定的值的不确定度的指南。由于不确定度声明中既有与材料无关的贡献，也有与材料有关的贡献，因此不可能给出该试验方法的绝对不确定度声明。ISO/IEC 指南 98-3[4]是一份基于严格统计方法对来自各种来源的不确定度进行汇总的 90 多页的综合文件。其复杂性促使许多组织编制了简化版本(见 NIS 80^[1.5]、NIS 3003^[16] 和参考文献[23])。这些文件都给出了基于“不确定度预算”概念评估测量不确定度的指南。详细描述见 EN 10291[11]和参考文献[24]。参考文献[25]和[26]提供了关于不确定度评估的更多信息。这里给出的测量不确定度并未描述材料不均匀性导致的分散性，例如来自一批材料、挤压型材或轧制卷材的起始和末尾，或铸件内不同位置的不均匀性。不确定度源于从理想均匀材料进行的不同试验、不同机器或不同实验室获得的数据的分散性。以下将描述不同的影响因素，并给出确定不确定度的指南。

The reproducibility values used in Tables K.2 to K.4 are half width intervals in accordance with ISO/IEC Guide 98-3[4] and should be interpreted as the value of plus and minus ($\pm$) scatter tolerances.

表 K.2 至 K.4 中使用的再现性值是根据 ISO/IEC 指南 98-3[4]的半宽度区间，应理解为正负 ($\pm$) 分散公差值。

K.2 Estimation of uncertainty

K.2 不确定度的评估

K.2.1 General

K.2.1 总则

The standard uncertainty, u , of the value of a parameter can be estimated in two ways.

参数值的标准不确定度 u 可以通过两种方式进行评估。

K.2.2 Type A - By repeated measurement

K.2.2 A 类 - 通过重复测量

$$u = \frac{s}{\sqrt{n}} \quad (\text{K.1})$$

where

其中

s is the standard deviation of the measurements;

s 是测量值的标准偏差；

n is the number of observations being averaged to report the result of the measurement under normal circumstances.

n 是在正常情况下为报告测量结果而进行平均的观测次数。

K.2.3 Type B — From some other source, e.g. calibration certificates or tolerances

K.2.3 B 类 — 来自其他一些来源，例如校准证书或公差

Here, the true value is equally likely to occur anywhere within the defined interval so the distribution is described as rectangular or uniform. Here the standard uncertainty is given by Formula (K.2):

在此，真值在定义区间内的任何位置出现的可能性均等，因此该分布被描述为矩形分布或均匀分布。这里，标准不确定度由公式 (K.2) 给出：

$$u = \frac{a}{\sqrt{3}} \quad (\text{K.2})$$

where a is half the width of the interval in which the quantity is assumed to lie.

其中 a 是假定该量所在区间宽度的一半。

Often the estimation of a quantity, y , involves the measurement of other quantities. The estimation of the uncertainty in y shall take account of the contributions of the uncertainties in all these measurements. It is thus known as a combined uncertainty. If the estimation simply involves the addition or subtraction of a series of measurements, $x_1, x_2 \dots x_n$, then the combined uncertainty in y , $u(y)$, is given by Formula (K.3):

通常，对一个量 y 的估计涉及对其他量的测量。对 y 不确定度的估计应考虑所有这些测量中不确定度的贡献。因此，它被称为合成不确定度。如果估计仅仅涉及一系列测量值 $x_1, x_2 \dots x_n$ 的相加或相减，那么 $y, u(y)$ 的合成不确定度由公式 (K.3) 给出：

$$u(y) = \sqrt{(u(x_1)^2 + u(x_2)^2 + \dots + u(x_n)^2)} \quad (\text{K.3})$$

where $u(x_1)$ is the uncertainty in the parameter x_1 , etc.

其中 $u(x_1)$ 是参数 x_1 等的不确定度。

K.3 Equipment parameters effect on the uncertainty of test results

K.3 设备参数对测试结果不确定度的影响

The uncertainty of the results determined from a tensile test contains components due to the equipment used. Various test results have differing uncertainty

contributions depending on the way they are determined. Table K. 1 indicates the equipment uncertainty contributions that should be considered for some of the more common material properties determined in a tensile test. Some of the test results can be determined with a lower uncertainty than others, e.g. the upper yield strength, R_{eH} , is only dependent on the uncertainties of measurement of force and cross-sectional area, while proof strength, R_n , is dependent on force, extension, gauge length, cross-sectional area, and other parameters. For reduction of area, Z , the measurement uncertainties of cross-sectional area both before and after fracture need to be considered.

拉伸试验确定结果的不确定度包含所使用设备产生的分量。根据确定方式的不同，各种测试结果的不确定度贡献也不同。表 K.1 列出了在拉伸试验中确定一些较常见材料性能时应考虑的设备不确定度贡献。一些测试结果可以比其他结果以更低的不确定度确定，例如，上屈服强度 R_{eH} 仅取决于力和横截面积测量的不确定度，而规定强度 R_n 则取决于力、伸长率、标距长度、横截面积和其他参数。对于断面收缩率 Z ，需要考虑断裂前后横截面积的测量不确定度。

Table K.1 — Uncertainty contributors to the test results, due to the measuring devices

表 K.1 — 测量设备对测试结果不确定度的贡献因素

Parameter	Test results					
	R_{eH}	$R_{el.}$	R_m	R_0	A	Z
Force	X	X	X	X	-	-
Extension	-	-	-	X	X	-
Gauge length	-	-	-	X	X	-
S_o	X	X	X	X	-	X
S_n	-	-	-	-	-	X
X Relevant. — Not relevant.						
参数	测试结果					
	R_{eH}	$R_{el.}$	R_m	R_0	A	Z
力	X	X	X	X	-	-
伸长	-	-	-	X	X	-
标距长度	-	-	-	X	X	-
S_o	X	X	X	X	-	X
S_n	-	-	-	-	-	X
X 相关。 — 不相关。						

The uncertainty of the test results listed in Table K.1 may be derived from the calibration certificates of the devices used for the determination of the test results.

For example, the standard uncertainty value for a force parameter using a machine with a certified uncertainty of 1,4 %, would be 1,4/2 or 0,70 %. It should be noted that a Class 1,0 classification (for the tensile testing machine or extensometer) does not necessarily guarantee an uncertainty of 1% . The uncertainty can be significantly higher or lower (for force example, see ISO 7500-1), and the equipment certificate should be consulted. Uncertainty contributions due to factors such as drift of the equipment since its calibration and its use in different environmental conditions should also be taken into account.

表 K.1 中列出的测试结果的不确定度可能源自用于确定测试结果的设备的校准证书。例如，使用经认证不确定度为 1.4%的机器时，力参数的标准不确定度值应为 1.4/2 或 0.70%。应当注意，1.0 级分类(针对拉伸试验机或引伸计)并不一定保证不确定度为 1%。不确定度可能显著更高或更低(例如对于力，参见 ISO 7500-1)，应查阅设备证书。还应考虑自校准以来设备的漂移以及在不同环境条件下使用等因素对不确定度的贡献。

Continuing the example according to Formula (K.3), taking account of the uncertainties in force or extensometer measurements, the combined uncertainty of the test results for R_{eH} , R_{eL} , R_m and A is

继续按照公式(K.3)的示例，考虑力或引伸计测量中的不确定度， R_{eH} , R_{eL} , R_m 和 A 的测试结果的合成不确定度为

$\sqrt{\left(\frac{1.4}{2}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2} = \sqrt{0.70^2 + 0.58^2} = 0.91\%$, using the square root of the sum of the squares approach.

$\sqrt{\left(\frac{1.4}{2}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2} = \sqrt{0.70^2 + 0.58^2} = 0.91\%$, 采用平方和的平方根法。

When estimating the uncertainty of R_p , it is not appropriate to simply apply the summation of the standard uncertainty components from the classification of the measuring devices. The force-extension curve shall be examined. For example, if the determination of R_n occurs on the force-extension curve at a point on the curve where the force indication does not change over the range of the extension measuring uncertainty, the uncertainty of the force indication due to the extension measuring device is insignificant. On the other hand, if the determination of R_D occurs on the force-extension curve at a point where the force is changing greatly in relation to the extension, the uncertainty in the reported force can be much greater than the uncertainty component due to the device classification. Additionally, the determination of the slope of the elastic part of the stress-percentage extension curve m_E can influence the result of R_p if the curve in this range is not an ideal straight line.

在估计 R_p 的不确定度时，简单应用测量设备分类中的标准不确定度分量之和是不合适的。应检查力-伸长曲线。例如，如果在力-伸长曲线上伸长测量不确定度范围

内力指示不变的点处确定 R_n ，则伸长测量设备引起的力指示不确定度可忽略不计。另一方面，如果在力-伸长曲线上力随伸长变化很大的点处确定 R_D ，则报告的力的不确定度可能远大于设备分类引起的不确定度分量。此外，如果该范围内的曲线不是理想直线，应力-伸长百分比曲线 m_E 的弹性部分斜率的确定可能会影响 R_p 的结果。

Table K.2 — Examples of uncertainty contributions for different test results, due to the measuring devices

表 K.2——测量设备对不同测试结果的不确定度贡献示例

Parameter	Uncertainty contribution ^a %				
	R_{eH}	R_{eL}	R_m	A	Z
Force	1,4	1,4	1,4	-	-
Extension	-	-	-	1,4	-
Gauge length, L_e, L_o	-	-	-	1	-
S_o	1	1	1	-	1
S_u	-	-	-	-	2
aValues are given for information only.					
参数	不确定度贡献 ^a %				
	R_{eH}	R_{eL}	R_m	A	Z
力	1,4	1,4	1,4	-	-
伸长量	-	-	-	1,4	-
标距, L_e, L_o	-	-	-	1	-
S_o	1	1	1	-	1
S_u	-	-	-	-	2
所提供的值仅用于参考。					

The combined uncertainty for Z, u_Z , expressed as a percentage, is given by Formula (K.4):

Z, u_Z 的合成不确定度，以百分比表示，由公式 (K.4) 给出：

$$u_Z = \sqrt{\left(\frac{a_{S_o}}{\sqrt{3}}\right)^2 + \left(\frac{a_{S_u}}{\sqrt{3}}\right)^2} = \sqrt{\left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{2}{\sqrt{3}}\right)^2} = \sqrt{0.577^2 + 1.155^2} = \sqrt{0.33 + 1.33} = 1,29 \quad (K.4)$$

Using a similar approach, examples of combined standard uncertainties for a range of testing results are shown in Table K.3.

采用类似方法，一系列测试结果的合成标准不确定度示例见表 K.3。

Table K.3 - Examples for combined uncertainty

表 K.3 - 合成不确定度示例

Combined uncertainty for different parameters				
%				
R_{eH}	R_{eL}	R_m	A	Z
0,91	0,91	0,91	0,91	1,29
不同参数的合成不确定度				
%				
R_{eH}	R_{eL}	R_m	A	Z
0,91	0,91	0,91	0,91	1,29

In accordance with ISO/IEC Guide 98-3^[4], the total expanded uncertainty is obtained by multiplying the combined standard uncertainties by a coverage function, k . For a 95 % level of confidence, $k = 2$.

根据 ISO/IEC 指南 98-3^[4]，合成标准不确定度乘以包含因子 k 得到合成扩展不确定度。对于 95 % 的置信水平， $k = 2$ 。

Table K. 4 — Examples for a 95% level of confidence, $k = 2$ (based on Table K.3)

表 K.4——95%置信水平的示例 $k = 2$ (基于表 K.3)

95% level of confidence, $k = 2$ for different parameters %				
R_{eH}	R_{eL}	R_m	A	Z
1,82	1,82	1,82	1,82	2,58
95% 置信水平， $k = 2$ 针对不同参数的百分比				
R_{eH}	R_{eL}	R_m	A	Z
1,82	1,82	1,82	1,82	2,58

Only uncertainty contributions with the same unit can be added in the calculation shown. For further information and more detailed information on measurement uncertainty in tensile testing, see CWA 15261-2[9] and Reference [27].

在所示计算中，只有具有相同单位的不确定度贡献才能相加。有关拉伸试验中测量不确定度的更多信息和详细信息，请参见 CWA 15261-2[9]和参考文献[27]。

It is highly recommended that scheduled periodic sample testing and charting of the standard deviation of the results related to a particular material test be performed. The resultant standard deviations of the data from the sample tests over time can provide a good indication of whether the test data uncertainty is within expectations.

强烈建议定期对特定材料试验的结果进行抽样测试并绘制结果标准差图表。随着时间推移，样本测试数据的最终标准差可以很好地表明测试数据的不确定度是否在预期范围内。

K.4 Parameters depending on the material and/or the test procedure

K.4 取决于材料和/或试验程序的参数

The precision of the test results from a tensile test is dependent upon factors related to the material being tested, the testing machine, the test procedure and the methods used to calculate the specified material properties. Ideally, all the following factors should be considered:

拉伸试验结果的精密度取决于与被测试材料、试验机、试验程序以及用于计算规定材料性能的方法相关的因素。理想情况下，应考虑以下所有因素：

a) test temperature;

a) 试验温度；

b) testing rates;

b) 试验速率；

c) the test piece geometry and machining;

c) 试件几何形状和加工；

d) the method of gripping the test piece and the axiality of the application of the force;

d) 夹持试件的方法和力的施加轴向性；

e) the testing machine characteristics (stiffness, drive and control mode);

e) 试验机特性(刚度、驱动和控制模式)；

f) human and software errors associated with the determination of the tensile properties;

f) 与拉伸性能测定相关的人为和软件误差；

g) extensometer mounting geometry.

g) 引伸计安装几何形状。

The influence of these factors depends on specific material behaviour and cannot be given as a defined value. If the influence is known, it can be taken into account in the calculation of the uncertainty as shown in K.3. It can be possible to include further sources of uncertainty in the estimation of the expanded measurement uncertainty. This can be done using the following approach.

这些因素的影响取决于特定材料的行为，无法给出确定值。如果已知其影响，则可按 K.3 中所示在不确定度计算中予以考虑。在扩展测量不确定度的估计中，可能还需纳入其他不确定度来源。可采用以下方法进行。

a) The user has to identify all additional possible sources, which can have an effect, directly or indirectly on the test parameter to be determined.

a) 用户必须识别所有可能直接或间接影响待确定试验参数的其他可能来源。

b) Relative contributions may vary according to the material tested and the special test conditions. Individual laboratories are encouraged to prepare a list of possible sources of uncertainty and evaluate their influence on the result. If a significant influence was determined, this uncertainty, u_i , has to be included in the calculation. The uncertainty, u_i , is the uncertainty of the source i on the value to be determined as a percentage as shown in Formula (K.3). For u_i the distribution function of the specific parameter (normal, rectangular, etc.) has to be identified. Then the influence on the result on the one sigma level has to be determined. This is the standard uncertainty.

b) 相对贡献可能因测试材料和特殊试验条件而异。鼓励各实验室编制一份可能的不确定度来源清单，并评估其对结果的影响。如果确定有显著影响，则此不确定度， u_i ，必须纳入计算。不确定度， u_i ，是来源 i 对待确定值的影响，以公式(K.3)所示的百分比表示。对于 u_i ，必须识别特定参数的分布函数(正态、矩形等)。然后必须确定在单标准差水平上对结果的影响。这就是标准不确定度。

Interlaboratory tests may be used to determine the overall uncertainty of results under conditions close to those used at industrial laboratories, but such tests do not separate effects related to the material inhomogeneity from those attributable to the testing method (see Annex L).

实验室间试验可用于确定接近工业实验室所用条件下结果的总体不确定度，但此类试验并未将与材料不均匀性相关的影响与测试方法所致影响区分开来(见附录 L)。

It should be appreciated that as suitable certified reference materials become available, they will offer a useful means of estimating the measurement uncertainty on any given testing machine including the influence of grips, bending, etc., which at present are difficult to quantify. An example of a certified reference material is BCR-661 (Nimonic 75) available from IRMM ¹⁾ (see CWA 15261-2[9]).

应当认识到，随着合适的有证参考材料的出现，它们将为估计任何给定试验机上的测量不确定度提供一种有用手段，包括夹具、弯曲等的影响，目前这些影响难以量

化。一种有证参考材料的例子是可从 IRMM¹⁾ 获得的 BCR-661(尼莫尼克 75)(见 CWA 15261-2[9])。

Alternatively, it is recommended that regular "in-house" tests be carried out for quality control purposes on material with a low level of scatter in properties (non-certified reference materials) (see Reference [28]).

另外，建议针对性能分散程度较低的材料(非认证参考材料)定期进行“内部”测试，以进行质量控制(见参考文献[28])。

There are some examples for which it is very difficult to give accurate uncertainty values without reference materials. When reliable uncertainty values are important, in some cases, the use of a certified reference material or non-certified reference material to confirm uncertainty of measurements is recommended. If no reference material can be used, suitable intercomparison exercises are needed (see References [21] and [30]).

在某些情况下，如果没有参考材料，很难给出准确的不确定度值。当可靠的不确定度值很重要时，在某些情况下，建议使用认证参考材料或非认证参考材料来确认测量的不确定度。如果无法使用参考材料，则需要进行适当的比对试验(见参考文献[21]和[30])。

1

Annex L

附录 L

(informative)

(资料性)

¹ 1) This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

1) 提供此信息是为了方便本文件的使用者，并不构成 ISO 对所述产品的认可。如果能证明等效产品能得出相同结果，则可以使用等效产品。

Precision of tensile testing - Results from interlaboratory programmes

拉伸试验的精密度——实验室间比对计划的结果

An indication of the typical scatter in tensile test results for a variety of materials that have been reported during laboratory intercomparison exercises, which include both material scatter and measurement uncertainty, is shown in Tables L. 1 to L.4. The results for the reproducibility are expressed as percentages calculated by multiplying by 2 the standard deviation of the respective parameter, e.g. R_p , R_m , Z , and A , and dividing the result by the mean value of the parameter, thereby giving values of reproducibility which represent the 95% confidence level, in accordance with the recommendations given in ISO/IEC Guide 98-3[4] and which may be directly compared with the expanded uncertainty values calculated by alternative methods.

表 L.1 至 L.4 给出了在实验室间比对试验中报告的各种材料拉伸试验结果的典型分散情况，其中包括材料分散和测量不确定度。再现性结果以百分比表示，计算方法是将相应参数的标准偏差乘以 2(例如 R_p , R_m , Z 和 A)，然后将结果除以该参数的平均值，从而得出代表 95% 置信水平的再现性值，符合 ISO/IEC 指南 98-3[4]中的建议，并且可以直接与通过其他方法计算的扩展不确定度值进行比较。

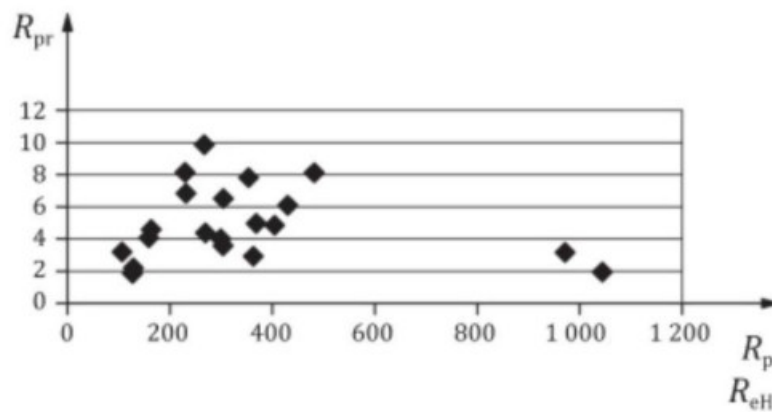
Table L.1 — Yield strengths (0,2 % proof strengths or upper yield strengths) — Reproducibility from laboratory intercomparison exercises (graphic presentation of the values is given in Figure L.1)

表 L.1——屈服强度(0.2% 规定塑性延伸强度或上屈服强度)——实验室间比对试验的再现性(图 L.1 给出了这些值的图形表示)

Material	Code	Yield strength MPa	Reproducibility ± %	Reference
Aluminium				
Sheet	AA5754	105,7	3,2	[31]
Sheet	AA5182-0	126,4	1,9	[20]
Sheet	AA6016-T4	127,2	2,2	[20]
	EC-H 19	158,4	4,1	[33]
	2024-T 351	362,9	3,0	[33]
Steel				
Sheet	DX56	162,0	4,6	[31]
Low carbon, plate	HR3	228,6	8,2	[34]

Sheet	ZStE 180	267,1	9,9	[31]
AISI 105	P245GH	367,4	5,0	[34]
	C22	402,4	4,9	[33]
Plate	S355	427,6	6,1	[31]
Austenitic S S	SS316L	230,7	6,9	[31]
Austenitic S S	X2CrNi18-10	303,8	6,5	[34]
Austenitic S S	X2CrNiMo18-10	353,3	7,8	[34]
AISI 316	X5CrNiMo17-12-2	480,1	8,1	[33]
Martensitic S S	X12Cr13	967,5	3,2	[33]
High Strength	30NiCrMo16	1039,9	2,0	[34]
Nickel alloys				
INCONEL 600	NiCr15Fe8	268,3	4,4	[33]
Nimonic 75	(BCR-661)	298,1	4,0	[29]
Nimonic 75	(BCR-661)	302,1	3,6	[31]
材料	代码	屈服强度 兆帕	再现性 ± %	参考文献
Aluminium				
板材	AA5754	105,7	3,2	[31]
板材	AA5182 - 0	126,4	1,9	[20]
板材	AA6016 - T4	127,2	2,2	[20]
	EC - H 19	158,4	4,1	[33]
	2024-T 351	362,9	3,0	[33]
钢				
板材	DX56	162,0	4,6	[31]
低碳, 板材	HR3	228,6	8,2	[34]
板材	ZStE 180	267,1	9,9	[31]
AISI 105	P245GH	367,4	5,0	[34]
	C22	402,4	4,9	[33]
板材	S355	427,6	6,1	[31]
奥氏体不锈钢	SS316L	230,7	6,9	[31]
奥氏体不锈钢	X2CrNi18 - 10	303,8	6,5	[34]

奥氏体不锈钢	X2CrNiMo18 - 10	353,3	7,8	[34]
AISI 316	X5CrNiMo17 - 12 - 2	480,1	8,1	[33]
马氏体不锈钢	X12Cr13	967,5	3,2	[33]
高强度	30NiCrMo16	1039,9	2,0	[34]
镍合金				
因科镍合金 600	NiCr15Fe8	268,3	4,4	[33]
尼莫尼克合金 75	(BCR - 661)	298,1	4,0	[29]
尼莫尼克合金 75	(BCR - 661)	302,1	3,6	[31]



Key

关键

R_{eH} upper yield strength, expressed in MPa

R_{eH} 上屈服强度，单位为兆帕(MPa)

R_p proof strength, expressed in MPa

R_p 规定强度，单位为兆帕(MPa)

R_{pr} reproducibility, expressed in %

R_{pr} 再现性，单位为 %

Figure L.1 — Presentation of the values given in Table L.1

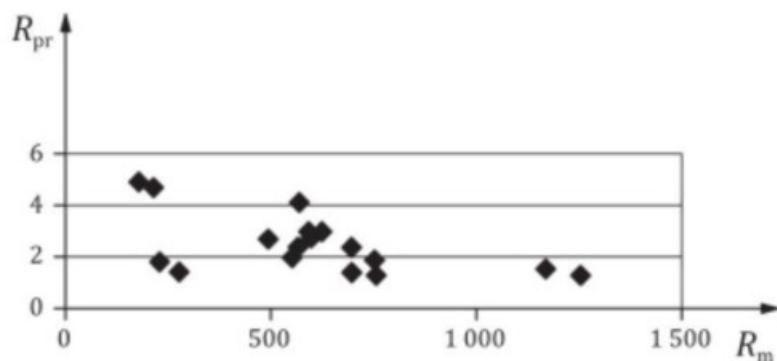
图 L.1 — 表 L.1 中给出的值的呈现

Table L.2 — Tensile strengths, R_m — Reproducibility from laboratory intercomparison exercises (graphic presentation of the values is given in Figure L.2)

表 L.2 — 抗拉强度， R_m — 实验室比对试验的再现性(图 L.2 给出了这些值的图形表示)

Material	Code	Tensile strength MPa	Reproducibility ± %	Reference
Aluminium				
Sheet	AA5754	212,3	4,7	[31]
Sheet	AA5182-0	275,2	1,4	[20]
Sheet	AA6016-T4	228,3	1,8	[20]
	EC-H 19	176,9	4,9	[33]
	2024-T 351	491,3	2,7	[33]
Steel				
Sheet	DX56	301,1	5,0	[31]
Low carbon, plate	HR3	335,2	5,0	[34]
Sheet	ZStE 180	315,3	4,2	[31]
AISI 105	Fe510C	552,4	2,0	[34]
	C22	596,9	2,8	[33]
Plate	\$355	564,9	2,4	[31]
Austenitic S S	SS316L	568,7	4,1	[31]
Austenitic S S	X2CrNi18-10	594,0	3,0	[34]
Austenitic S S	X2CrNiMo18-10	622,5	3,0	[34]
AISI 316	X7CrNiMo17-12-2	694,6	2,4	[33]
Martensitic S S	X12Cr13	1 253,0	1,3	[33]
High Strength	30NiCrMo16	1167,8	1,5	[34]
材料	代码	抗拉强度 兆帕	再现性 ± %	参考文献
铝				
板材	AA5754	212,3	4,7	[31]
板材	AA5182-0	275,2	1,4	[20]

板材	AA6016-T4	228,3	1,8	[20]
	EC-H 19	176,9	4,9	[33]
	2024-T 351	491,3	2,7	[33]
钢				
板材	DX56	301,1	5,0	[31]
低碳, 板材	HR3	335,2	5,0	[34]
板材	ZStE 180	315,3	4,2	[31]
AISI 105	Fe510C	552,4	2,0	[34]
	C22	596,9	2,8	[33]
板材	\$355	564,9	2,4	[31]
奥氏体不锈钢	SS316L	568,7	4,1	[31]
奥氏体不锈钢	X2CrNi18-10	594,0	3,0	[34]
奥氏体不锈钢	X2CrNiMo18-10	622,5	3,0	[34]
AISI 316	X7CrNiMo17-12-2	694,6	2,4	[33]
马氏体不锈钢	X12Cr13	1 253,0	1,3	[33]
高强度	30NiCrMo16	1167,8	1,5	[34]
Material	Code	Tensile strength MPa	Reproducibility $\pm$ %	Reference
Nickel alloys				
INCONEL 600	NiCr15Fe8	695,9	1,4	[33]
Nimonic 75	(BCR-661)	749,6	1,9	[29]
Nimonic 75	(BCR-661)	754,2	1,3	[31]
材料	代码	抗拉强度 兆帕	再现性 $\pm$ %	参考文献
镍合金				
因科镍合金 600	NiCr15Fe8	695,9	1,4	[33]
尼莫尼克合金 75	(BCR - 661)	749,6	1,9	[29]
尼莫尼克合金 75	(BCR - 661)	754,2	1,3	[31]



Key

关键

R_m tensile strength, expressed in MPa

R_m 抗拉强度，以 MPa 表示

R_{pr} reproducibility, expressed in %

R_{pr} 再现性，以 % 表示

Figure L.2 - Presentation of the values given in Table L.2

图 L.2 - 表 L.2 中给出的值的展示

Table L.3 — Elongation after fracture — Reproducibility from laboratory intercomparison exercises (graphic presentation of the values is given in Figure L.3)

表 L.3 — 断裂后伸长率 — 实验室比对试验的再现性(图 L.3 给出了这些值的图形展示)

Material	Code	Elongation after fracture A	Reproducibility $\pm$	Reference
		%	% ^a	
Aluminium				
Sheet	AA5754	27,9	13,3	[31]
Sheet	AA5182-0	26,6($A_{80 \text{ mm}}$)	10,6	[20]
Sheet	AA6016-T4	25,9($A_{80 \text{ mm}}$)	8,4	[20]
	EC-H 19	14,6	9,1	[33]
	2024-T 351	18,0	18,9 ^a	[33]
Steel				

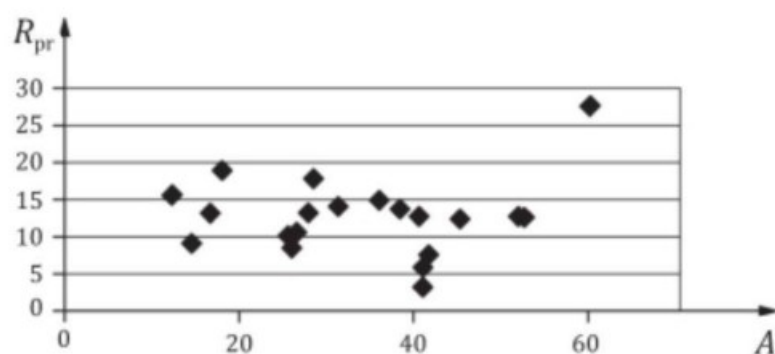
Sheet	DX56	45,2	12,4	[31]
Low carbon, plate	HR3	38,4	13,8	[34]
Sheet	ZstE 180	40,5	12,7	[31]
AISI 105	Fe510C	31,4	14,0	[34]
	C22	25,6	10,1	[33]
Plate	\$355	28,5	17,7	[31]
Austenitic S S	SS316L	60,1	27,6	[31]
Austenitic S S	X2CrNi18-10	52,5	12,6	[34]
Austenitic S S	X2CrNiMo18-10	51,9	12,7	[34]
AISI 316	X5CrNiMo17-12-2	35,9	14,9	[33]
Martensitic S S	X12Cr13	12,4	15,5	[33]
High Strength	30NiCrMo16	16,7	13,3	[34]
Nickel alloys				
INCONEL 600	NiCr15Fe8	41,6	7,7	[33]
Nimonic 75	(BCR-661)	41,0	3,3	[29]
Nimonic 75	(BCR-661)	41,0	5,9	[31]
材料	代码	断裂后伸长率 A	再现性 $\pm$	参考文献
		%	% ^a	
铝				
板材	AA5754	27,9	13,3	[31]
板材	AA5182 - 0	26,6($A_{80 \text{ mm}}$)	10,6	[20]
板材	AA6016 - T4	25,9($A_{80 \text{ mm}}$)	8,4	[20]
	EC - H 19	14,6	9,1	[33]
	2024-T 351	18,0	18 _n 9 ^a	[33]
钢				
板材	DX56	45,2	12,4	[31]
低碳, 板材	HR3	38,4	13,8	[34]
板材	ZstE 180	40,5	12,7	[31]
AISI 105	Fe510C	31,4	14,0	[34]
	C22	25,6	10,1	[33]

板材	\$355	28,5	17,7	[31]
奥氏体不锈钢	SS316L	60,1	27,6	[31]
奥氏体不锈钢	X2CrNi18 - 10	52,5	12,6	[34]
奥氏体不锈钢	X2CrNiMo18 - 10	51,9	12,7	[34]
AISI 316	X5CrNiMo17 - 12 - 2	35,9	14,9	[33]
马氏体不锈钢	X12Cr13	12,4	15,5	[33]
高强度	30NiCrMo16	16,7	13,3	[34]
镍合金				
因科镍合金 600	NiCr15Fe8	41,6	7,7	[33]
尼莫尼克合金 75	(BCR - 661)	41,0	3,3	[29]
尼莫尼克合金 75	(BCR - 661)	41,0	5,9	[31]

a The reproducibility is expressed as a percentage of the respective mean value of A for the given material; thus, for 2024

a 再现性以给定材料的 A 各自平均值的百分比表示；因此，对于 2024

- T 351 aluminium, the absolute value of A is $(18,0 \pm 3,4)\%$.
- T 351 铝合金， A 的绝对值为 $(18,0 \pm 3,4)\%$ 。



Key

关键

A elongation after fracture, expressed in %

A 断裂后伸长率，以%表示

*R*_{pr} reproducibility, expressed in %

*R*_{pr} 再现性，以 % 表示

Figure L.3 - Presentation of the values given in Table L.3

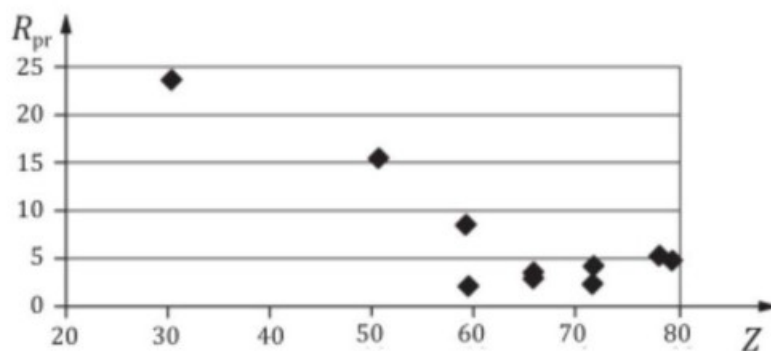
图 L.3 - 表 L.3 中给出的值的展示

Material	Code	Reduction of area	Reproducibility ±	Reference
		<i>Z</i>	% a	
		%		
Aluminium				
	EC-H 19	79,1	5,1	[33]
	2024-T 351	30,3	23 _a 7 ^b	[33]
Steel				
Low carbon, plate	HR3			
AISI 105	Fe510C	71.4	2,7	[34]
	C22	65,6	3,8	[33]
Austenitic S S	X2CrNi18-10			
Austenitic S S	X2CrNiMo18-10	77,9	5,6	[34]
AISI 316	X5CrNiMo17-12-2	71,5	4,5	[33]
Martensitic S S	X12Cr13	50,5	15,6b	[33]
High Strength	30NiCrMo16	65,6	3,2	[34]
Nickel alloys				
INCONEL 600	NiCr15Fe8	59,3	2,4	[33]
Nimonic 75	(BCR-661)	59,0	8,8	[29]
材料	代码	面积减小	再现性 ±	参考文献
		<i>Z</i>	% a	

		%		
铝				
	EC-H 19	79,1	5,1	[33]
	2024-T 351	30,3	23 _a 7 ^b	[33]
钢				
低碳钢板	HR3			
AISI 105	Fe510C	71,4	2,7	[34]
	C22	65,6	3,8	[33]
奥氏体不锈钢	X2CrNi18 - 10			
奥氏体不锈钢	X2CrNiMo18 - 10	77,9	5,6	[34]
AISI 316	X5CrNiMo17 - 12 - 2	71,5	4,5	[33]
马氏体不锈钢	X12Cr13	50,5	15,6b	[33]
高强度	30NiCrMo16	65,6	3,2	[34]
镍合金				
因科镍合金 600	NiCr15Fe8	59,3	2,4	[33]
尼莫尼克合金 75	(BCR - 661)	59,0	8,8	[29]

Table L.4 — Reduction of area Z — Reproducibility from laboratory intercomparison exercises (graphic presentation of the values is given in Figure L.4) a The reproducibility is expressed as a percentage of the respective mean value of Z for the given material; thus, for the 2024-T 351 aluminium, the absolute value of Z is $(30,3 \pm 7,2)\%$. b Some of the values of reproducibility may appear to be relatively high; such values probably indicate the difficulty of reliably measuring the dimensions of the test piece in the necked region of the fracture. For thin sheet test pieces, the uncertainty of measurement of the thickness of the test piece may be large. Likewise, the measurement of the diameter or thickness of the test piece in the necked region is highly dependent upon the skill and experience of the operator.

表 L.4——断面收缩率 Z ——实验室比对试验的再现性(图 L.4 给出了这些值的图形表示)a 再现性以给定材料的 Z 各自平均值的百分比表示; 因此, 对于 2024-T 351 铝合金, Z 的绝对值为 $(30,3 \pm 7,2)\%$ 。b 一些再现性值可能看起来相对较高; 这些值可能表明在断裂的缩颈区域可靠测量试件尺寸存在困难。对于薄板试件, 试件厚度的测量不确定度可能较大。同样, 在缩颈区域测量试件的直径或厚度高度依赖于操作人员的技能和经验。



Key

关键词

R_{pr} reproducibility, expressed in %

以 % 表示的 R_{pr} 再现性

Z reduction of area, expressed in %

以%表示的 Z 断面收缩率

Figure L.4 - Presentation of the values given in Table L.4

图 L.4——表 L.4 中给出的值的表示

Bibliography

##参考文献

[1] ISO 3183, Petroleum and natural gas industries — Steel pipe for pipeline transportation systems

ISO 3183, 石油和天然气工业——管道输送系统用钢管

[2] ISO 11960, Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells

ISO 11960, 石油和天然气工业——油井用套管或油管

[3] ISO/TR 25679, Mechanical testing of metals — Symbols and definitions in published standards

ISO/TR 25679, 金属材料力学试验——已发布标准中的符号和定义

[4] ISO/IEC Guide 98-3, Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

ISO/IEC 指南 98-3, 测量不确定度——第 3 部分:测量不确定度表示指南
(GUM:1995)

[5] ISO/TTA 2, Tensile tests for discontinuously reinforced metal matrix composites at ambient temperatures

ISO/TTA 2, 室温下不连续增强金属基复合材料的拉伸试验

[6] ASTM A370, Standard test methods and definitions for mechanical testing of steel products

ASTM A370, 钢产品力学试验的标准试验方法和定义

[7] ASTM E8M, Standard test methods for tension testing of metallic materials

ASTM E8M, 金属材料拉伸试验的标准试验方法

[8] ASTM E1012, Standard practice for verification of test frame and specimen alignment under tensile and compressive axial force application

ASTM E1012, 在拉伸和压缩轴向力作用下试验框架和试样对准验证的标准实施规程

[9] CWA 15261-2:2005, Measurement uncertainties in mechanical tests on metallic materials- Part 2: The evaluation of uncertainties in tensile testing

CWA 15261-2:2005, 金属材料力学试验中的测量不确定度——第 2 部分:拉伸试验不确定度的评估

[10] DIN 50125, Testing of metallic materials - Tensile test pieces

DIN 50125, 金属材料试验——拉伸试样

[11] EN 10291, Metallic materials - Uniaxial creep testing in tension - Methods of test

EN 10291, 金属材料——拉伸单轴蠕变试验——试验方法

[12] GB/T 228, Metallic materials - Tensile testing at ambient temperature

GB/T 228, 金属材料——室温拉伸试验

[13] IACS W2 Test specimens and mechanical testing procedures for materials. In: Requirements concerning materials and welding, pp. W2-1 to W2-10. International Association of Classification Societies, London, 2003. Available (2008-06-26) at: http://www.iacs.org.uk/document/public/publications/unified_requirements/pdf/ur_w_pdf159.pdf

国际船级社协会(IACS)W2 材料的试样和机械试验程序。见:材料与焊接要求, 第 W2 - 1 至 W2 - 10 页。国际船级社协会, 伦敦, 2003 年。可获取(2008 - 06 - 26)

于:http://www.iacs.org.uk/document/public/publications/unified_requirements/pdf/ur_w_pdf159.pdf

[14] JIS Z2241, Test pieces for tensile test for metallic materials

JIS Z2241, 金属材料拉伸试验用试样

[15] NIS 80:1994, Guide to the expression of uncertainty in testing

NIS 80:1994, 测试中不确定度的表示指南

[16] NIS 3003:1995. The expression of uncertainty and confidence in measurement

NIS 3003:1995, 测量中不确定度和置信度的表示

[17] DEAN G.D., Lovebay M.S., Cooper P.M., READ B.E., ROEBUCK B., MORRELL R. Aspects of modulus measurement. In: DYSON, B.G., LOVEDAY, M.S., GEE, M.G., editors. Materials metrology and standards for structural performance, pp. 150-209. Chapman & Hall, London, 1995

迪恩 • G.D.、洛夫贝伊 • M.S.、库珀 • P.M.、里德 • B.E.、罗巴克 • B.、莫雷尔 • R. 模量测量的若干方面。见:戴森, B.G.、洛夫戴, M.S.、吉, M.G. 编辑。结构性能的材料计量与标准, 第 150 - 209 页。查普曼与霍尔出版社, 伦敦, 1995 年

[18] ROEBUCK B., LORD J.D., COOPER P.M., MCCARTNEY L.N., Data acquisition and analysis of tensile properties for metal matrix composites. J. Test. Eval. 1994, 22 (1) pp. 63-69

罗巴克 • B.、洛德 • J.D.、库珀 • P.M.、麦卡特尼 • L.N. 金属基复合材料拉伸性能的数据采集与分析。《测试与评估杂志》1994 年, 第 22 卷第 1 期, 第 63 - 69 页

[19] SONNE H.M., HESSE B. B. Determination of Young's modulus on steel sheet by computerised tensile test - Comparison of different evaluation concepts. In: Proceedings of Werkstoffprüfung [Materials testing] 1993. DVM, Berlin

索内 • H.M.、黑塞 • B.B. 通过计算机控制拉伸试验测定钢板的杨氏模量——不同评估概念的比较。见:《材料测试》会议论文集 1993 年。德国材料试验协会(DVM), 柏林

[20] AEGERTER J., KELLER S., WIESER D. Prüfvorschrift zur Durchführung und Auswertung des Zugversuches für Al-Werkstoffe [Test procedure for the accomplishment and evaluation of the tensile test for aluminium and aluminium alloys], In: Proceedings of Werkstoffprüfung [Materials testing] 2003, pp. 139-150. Stahleisen, Düsseldorf

埃格特 • J.、凯勒 • S.、维泽 • D. 铝及铝合金拉伸试验的实施与评估试验规程, 见:《材料测试》会议论文集 2003 年, 第 139 - 150 页。施塔勒森出版社, 杜塞尔多夫

[21] RIDES M., LORD J. TENSTAND final report: Computer-controlled tensile testing according to EN 10002-1: Results of a comparison test programme to validate a proposal for an amendment of the standard. National Physical Laboratory, Teddington, 2005

里兹 • M.、洛德 • J. TENSTAND 最终报告:根据 EN 10002 - 1 进行的计算机控制拉伸试验:验证标准修订提案的比较试验计划结果。国家物理实验室, 特丁顿, 2005 年

[22] LORD J., LOVEDAY M.S., RIDES M., MCENTAGGART I. TENSTAND WP2 final report: Digital tensile software evaluation: Computer-controlled tensile testing machines validation of European Standard EN 10002-1. National Physical Laboratory, Teddington, 2005, 68 p. Available at: <http://eprintspublications.npl.co.uk/3224/>

洛德 • J.、洛夫戴 • M.S.、里兹 • M.、麦克恩塔加特 • I. TENSTAND WP2 最终报告:数字拉伸软件评估:欧洲标准 EN 10002 - 1 的计算机控制拉伸试验机验证。国家物理实验室, 特丁顿, 2005 年, 68 页。可获取于:<http://eprintspublications.npl.co.uk/3224/>

[23] TAYLOR B.N., KUYATT C.E. Guidelines for evaluating and expressing the uncertainty of NIST measurement results. NIST, Gaithersburg, MD, 1994. 25 p. (NIST Technical Note 1297.) Available (2009-07-23) at: <http://physics.nist.gov/Pubs/guidelines/TN1297/tn1297s.pdf>

B.N. 泰勒、C.E. 库亚特。评估和表示美国国家标准与技术研究院(NIST)测量结果不确定度的指南。美国国家标准与技术研究院, 盖瑟斯堡, 马里兰州, 1994 年。25 页。(NIST 技术报告 1297)。可获取(2009 - 07 - 23)于:<http://physics.nist.gov/Pubs/guidelines/TN1297/tn1297s.pdf>

[24] LOVEDAY M.S. Room temperature tensile testing: A method for estimating uncertainty of measurement. National Physical Laboratory, Teddington, 1999. [Measurement note CMMT (MN) 048.] Available (2009-07-23) at: <http://eprintspublications.npl.co.uk/2438/>

洛夫戴 • M.S. 室温拉伸试验:测量不确定度的估计方法。国家物理实验室, 特丁顿, 1999 年。[测量报告 CMMT(MN)048]。可获取(至 2009 - 07 - 23)于:<http://eprintspublications.npl.co.uk/2438/>

[25] BELL S.A. 1999) A beginner's guide to uncertainty of measurement, 2nd edition. National Physical Laboratory, Teddington, 2001. 41 p. (Measurement Good Practice Guide, No. 11.) Available (2009- 07-31) at: <http://eprintspublications.npl.co.uk/1568/>

贝尔 • S.A. 1999 年)测量不确定度入门指南, 第 2 版。国家物理实验室, 特丁顿, 2001 年。41 页。(测量良好实践指南, 第 11 号)。可获取(2009 - 07 - 31)于:<http://eprintspublications.npl.co.uk/1568/>

[26] BIRCH K. Estimating uncertainties in testing. National Physical Laboratory, Teddington, 2001. (Measurement Good Practice Guide, No. 36.) Available (2009-07-23) at: <http://eprintspublications.npl.co.uk/2022/>

伯奇 • K. 测试中不确定度的估计。国家物理实验室，特丁顿，2001 年。(测量良好实践指南，第 36 号)。可获取(2009 - 07 - 23)
于:<http://eprintspublications.npl.co.uk/2022/>

[27] Kandil F.A., Lord J.D., Bullough C.K., Georgsson P., Legendre L., Money G. et al. The UNCERT manual of codes of practice for the determination of uncertainties in mechanical tests on metallic materials [CD-ROM]. EC, Brussels

坎迪尔 • F • A、洛德 • J • D、布洛赫 • C • K、乔治松 • P、勒让德 • L、莫尼 • G 等。《金属材料力学试验不确定度测定的 UNCERT 实用规范手册》[光盘]。欧盟委员会，布鲁塞尔

[28] SONNE H.M., KNAUF G., SCHMIDT-ZINGES J. Überlegungen zur Überprüfung von Zugprüfmaschinen mittels Referenzmaterial [Considerations on the examination of course test equipment by means of reference material]. In: Proceedings of Werkstoffprüfung [Materials testing] 1996. Bad Nauheim. DVM, Berlin

松内 • H • M、克瑙夫 • G、施密特 - 津格斯 • J。关于使用参考材料检验拉伸试验机的思考[关于通过参考材料检验拉伸试验设备的思考]。载于:《材料测试》会议论文集，1996 年。巴特瑙海姆。德国材料试验协会(DVM)，柏林

[29] INGELBRECHT C.D., LOVEDAY M.S., The certification of ambient temperature tensile properties of a reference material for tensile testing according to EN 10002-1: CRM 661. EC, Brussels, 2000. (BCR Report EUR 19589 EN.)

英格尔布雷希特 • C • D、洛夫迪 • M • S。根据 EN 10002 - 1 对拉伸试验参考材料室温拉伸性能的认证:CRM 661。欧盟委员会，布鲁塞尔，2000 年。(BCR 报告 EUR 19589 EN。)

[30] L1 H.-P., Zhou X. New Consideration on the uncertainty evaluation with measured values of steel sheet in tensile testing. In: Metallurgical analysis, 12th Annual Conference of Analysis Test of Chinese Society for Metals, 2004

李 • H - P、周 X。关于钢板拉伸试验测量值不确定度评估的新思考。载于:《冶金分析》，中国金属学会分析测试分会第 12 届年会，2004 年

[31] KLINGELHÖFFER H., LEDWORUSKI S., BROOKES S., MAY T. Computer controlled tensile testing according to EN 10002-1 - Results of a comparison test programme to validate a proposal for an amendment of the standard - Final report of the European project TENSTAND - Work Package 4. Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, 2005. 44 p. (Forschungsbericht [Technical report] 268.) Available (2008-07-01) at: http://www.bam.de/de/service/publikationen/publikationen_medien/fb268_vt.pdf

克林格尔霍费尔·H、莱德沃鲁斯基·S、布鲁克斯·S、梅·T。根据 EN 10002 - 1 进行的计算机控制拉伸试验——验证标准修订提案的比较试验计划结果——欧洲项目 TENSTAND 工作包 4 的最终报告。德国材料研究与测试联邦研究所(BAM), 柏林, 2005 年。44 页。(技术报告 268。)可获取(2008 - 07 - 01)
于:http://www.bam.de/de/service/publikationen/publikationen_medien/fb268_vt.pdf

[32] LOVEDAY M.S., GRAY T., AEGERTER J. Tensile testing of metallic materials A review Final report of the TENSTAND project of work package 1. Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, 2004

洛夫迪·M·S、格雷·T·、埃格特·J。金属材料的拉伸试验——综述——TENSTAND 项目工作包 1 的最终报告。德国材料研究与测试联邦研究所(BAM), 柏林, 2004 年

[33] ASTM Research Report E 28 1004:1994, Round robin results of interlaboratory tensile tests

ASTM 研究报告 E 28 1004:1994, 实验室间拉伸试验的循环试验结果

[34] ROESCH L., COUE N., VITALI J., di FANT M. Results of an interlaboratory test programme on room temperature tensile properties — Standard deviation of the measured values. (IRSID Report, NDT 93310.)

勒施·L、库埃·N、维塔利·J、迪·法恩特·M。室温拉伸性能实验室间试验计划结果——测量值的标准偏差。(IRSID 报告, NDT 93310。)

[35] Lovebay M.S. Towards a tensile reference material. In: Loveday, M.S., Gibbons, T.B. Harmonisation of testing practice for high temperature materials. Elsevier, London, pp. 111-53.

洛夫贝·M·S。迈向拉伸参考材料。载于:洛夫迪, M·S、吉本斯, T·B。高温材料测试实践的协调。爱思唯尔, 伦敦, 第 111 - 153 页。

[36] JOHNSON R.F., MURRAY J.D., The effect of rate of straining on the 0.2% proof stress and lower yield stress of steel. In: Proceedings of Symposium on High Temperature Performance of Steels, Eastbourne, 1966. Iron and Steel Institute, 1967

约翰逊·R·F、默里·J·D。应变速率对钢的 0.2% 规定塑性延伸强度和下屈服强度的影响。载于:《钢的高温性能研讨会论文集》, 伊斯特本, 1966 年。钢铁协会, 1967 年

[37] GRAY T.G.F., SHARP J. Influence of machine type and strain rate interaction in tension testing. In: PAPIRNO, R., WEISS, H.C. Factors that affect the precision of mechanical tests. ASTM, Philadelphia, PA. (Special Technical Publication 1025.)

格雷·T·G·F、夏普·J。拉伸试验中机器类型和应变速率相互作用的影响。载于:帕皮尔诺, R、魏斯, H·C。影响力学试验精度的因素。ASTM, 宾夕法尼亚州费城。(特别技术出版物 1025。)

[38] AEGERTER J., BLOCHING H., SONNE H.-M., Influence of the testing speed on the yield/proof strength — Tensile testing in compliance with EN 10002-1. Materialprüfung. 2001, 10 pp. 393-403

埃格特·J、布洛欣·H、松内·H-M。试验速度对屈服/规定强度的影响——符合 EN 10002 - 1 的拉伸试验。材料测试。2001 年, 10 页, 第 393 - 403 页

[39] AEGERTER, J. Strain rate at a given point of a stress/strain curve in the tensile test [Internal memorandum], VAW Aluminium, Bonn, 2000

埃格特, J。拉伸试验中应力/应变曲线给定点的应变速率[内部备忘录], VAW 铝业公司, 波恩, 2000 年

[40] BLOCHING H. Calculation of the necessary crosshead velocity in mm/min for achieving a specified stress rate in MPa/s. Zwick, Ulm, 2000, 8 p. [Report]

布洛欣·H。为达到以 MPa/s 为单位的規定应力速率计算所需十字头速度(单位:mm/min)。兹维克公司, 乌尔姆, 2000 年, 8 页[报告]

[41] MCENTEGGART I., LOHR R.D. Mechanical testing machine criteria. In: Dyson, B.G., LovEDAY, M.S., GEE, M.G., editors. Materials metrology and standards for structural performance, pp. 19-33. Chapman & Hall, London, 1995

麦肯泰加特·I、洛尔·R·D。力学试验机标准。载于:戴森, B·G、洛夫迪, M·S、吉, M·G 编。结构性能的材料计量与标准, 第 19 - 33 页。查普曼与霍尔出版社, 伦敦, 1995 年

[42] Austin T., Bullough C., Leal D., Gagiliardi D., Lovebay M., A Guide to the Development and Use of Standards Compliant Data Formats for Engineering Materials Test Data, CEN CWA 162002010:
ftp://ftp.cen.eu/CEN/Sectors/List/ICT/CWAs/CWA16200-2010_ELSSI.pdf

奥斯汀·T、布洛赫·C、利尔·D、加吉利亚迪·D、洛夫贝伊·M, 《工程材料试验数据符合标准的数据格式开发与使用指南》, CEN CWA 162002010:
ftp://ftp.cen.eu/CEN/Sectors/List/ICT/CWAs/CWA16200-2010_ELSSI.pdf

[43] SEP 1235, Determination of the modulus of elasticity on steels by tensile testing at room temperature, Stahl-Eisen-Prüfblatt (SEP) des Stahlinstituts VDEh, Düsseldorf

SEP 1235, 《室温下通过拉伸试验测定钢的弹性模量》, 德国钢铁协会(VDEh)钢铁检验标准(SEP), 杜塞尔多夫

[44] LORD J.D, ORKNEY L.P Elevated Temperature Modulus Measurements Using the Impulse Excitation Technique (IET). NPL Measurement Note CMMT. MN, 2000, pp. 049. Available at: <http://eprintspublications.npl.co.uk/3249/>

洛德·J.D、奥克尼·L.P, 《使用脉冲激励技术(IET)进行高温模量测量》。国家物理实验室测量报告 CMMT.MN, 2000 年, 第 049 页。可在:<http://eprintspublications.npl.co.uk/3249/>获取

[45] LORD J.D, ORKNEY L.P Measurement Good Practice Guide No. 98 Elastic Modulus Measurement, ISSN 1744-3911 (2006). Available at: <http://eprintspublications.npl.co.uk/3782/>

洛德·J.D、奥克尼·L.P, 《测量良好实践指南第 98 号:弹性模量测量》, ISSN 1744 - 3911(2006 年)。可在:<http://eprintspublications.npl.co.uk/3782/>获取

[46] CARPENTER M*, NUNN J, Impulse Excitation Modulus measurements of Hardmetal Rods using custom software on a standard personal computer and microphone. Mater. Eval. 2012, 70 (7) pp. 863-871

卡彭特·M*、纳恩·J, 《使用标准个人电脑和麦克风上的定制软件对硬质合金棒进行脉冲激励模量测量》。《材料评估》, 2012 年, 70(7), 第 863 - 871 页

[47] GABAUER W, The Determination of Uncertainties in Tensile Testing UNCERT COP 07: 2000

加鲍尔·W, 《拉伸试验不确定度的测定》, UNCERT COP 07:2000

[48] BULLOUGH C. K, The Determination of Uncertainties in Dynamic Young's Modulus UNCERT CoP 13:2000

布洛赫·C.K, 《动态杨氏模量不确定度的测定》, UNCERT CoP 13:2000

[49] LORD J., RIDES M., LOVEDAY M. Modulus Measurement Methods TENSTAND WP3 Final Report NPL REPORT DEPC MPE 016 Jan 2005. ISSN 1744-0262. Available at: <http://eprintspublications.npl.co.uk/3223/>

洛德·J、里兹·M、洛夫迪·M, 《模量测量方法》, TENSTAND WP3 最终报告, 国家物理实验室报告 DEPC MPE 016, 2005 年 1 月。ISSN 1744 - 0262。可在:<http://eprintspublications.npl.co.uk/3223/>获取

[50] UNWIN W.C., The testing of materials of construction. Longmans, Green & Co, London, 1910, pp. 237-8.

昂温·W.C, 《建筑材料测试》。朗文格林公司, 伦敦, 1910 年, 第 237 - 238 页

[51] LORD J.D., ROEBUCK B., ORKNEY L.P. Validation of a draft tensile testing standard for discontinuously reinforced MMC, VAMAS Report No.20, National Physical Laboratory, May 1995

洛德·J.D、罗巴克·B、奥克尼·L.P, 《间断增强金属基复合材料拉伸试验标准草案的验证》, VAMAS 报告第 20 号, 国家物理实验室, 1995 年 5 月

[52] ASTM E 111, Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

ASTM E 111, 《杨氏模量、切线模量和弦模量的标准试验方法》

[53] AEGERTER J., FRENZ H., KÜHN H.-J., WEISSMÜLER C., ISO 6892-1:2009 Tensile Testing: Initial Experience from the Practical Implementation of the New Standard, Carl Hanser Verlag, München, Vol. 53, (2011) 10, pp. 595-603, correction of Fig. 6 in Carl Hanser Verlag, München, Vol. 53, (2011) 11

埃格特·J、弗伦茨·H、库恩·H-J、魏斯穆勒·C, 《ISO 6892 - 1:2009 拉伸试验:新标准实际实施的初步经验》, 卡尔·汉斯 er 出版社, 慕尼黑, 第 53 卷, (2011 年)10 期, 第 595 - 603 页, 卡尔·汉斯 er 出版社, 慕尼黑, 第 53 卷, (2011 年)11 期对图 6 的修正

[54] WEISSMÜLER C., FRENZ H., Measurement Uncertainty for the Determination of Young's Modulus on Steel, Materials Testing, Carl Hanser Verlag, München, 2013, Vol. 55 No. 9, pp. 643- 647, available at: <http://www.hanser-elibrary.com/doi/pdf/10.3139/120.110482>

魏斯穆勒·C、弗伦茨·H, 《钢的杨氏模量测定中的测量不确定度》, 《材料测试》, 卡尔·汉斯 er 出版社, 慕尼黑, 2013 年, 第 55 卷第 9 期, 第 643 - 647 页, 可在:<http://www.hanser-elibrary.com/doi/pdf/10.3139/120.110482> 获取

[55] ISO 377, Steel and steel products - Location and preparation of samples and test pieces for mechanical testing

ISO 377, 《钢和钢产品 - 机械性能试验用样品和试件的位置与制备》

[56] ISO 2566-1, Steel - Conversion of elongation values - Part 1: Carbon and low alloy steels

ISO 2566 - 1, 《钢 - 伸长率值的换算 - 第 1 部分:碳钢和低合金钢》

[57] ISO 2566-2, Steel - Conversion of elongation values - Part 2: Austenitic steels

ISO 2566 - 2, 《钢 - 伸长率值的换算 - 第 2 部分:奥氏体钢》

[58] ISO 80000-1, Quantities and units - Part 1: General

ISO 80000-1, 量和单位 - 第 1 部分:总则

[59] ISO 23788, Metallic materials - Verification of the alignment of fatigue testing machines

ISO 23788, 金属材料 - 疲劳试验机校准的验证

ISO 6892-1:2019(E)

ISO 6892-1:2019(英文版)

ISO 6892-1:2019(E)

ISO 6892-1:2019(英文版)

ICS 77.040.10 Price based on 78 pages © ISO 2019 - All rights reserved

国际标准分类号 ICS 77.040.10 基于 78 页 版权所有©ISO©ISO 2019 - 保留所有权利