INTERNATIONAL STANDARD

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Second edition
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Metallic materials — Determination of forming-limit curves for sheet and strip —

Part 2:
Determination of forming-limit curves in the laboratory

Matériaux métalliques — Détermination des courbes limites de formage pour les tôles et bandes —

Partie 2: Détermination des courbes limites de formage en laboratoire

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Foreword

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

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

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

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.

This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459/SC 1, *Test methods for steel (other than chemical analysis),* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 12004-2:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

1) The title was changed to have three elements.

2) Clause 2 and Clause 3 were added from the previous edition, and the subsequent clauses were renumbered.

3) The descriptions of when to use ISO 12004-1 or ISO 12004-2 (this document) was revised in the Introduction.

4) Permissions and requirements were clarified in 6.1.3, 6.1.5, 6.2.2, 6.2.3, 6.3.2, 6.3.3.3, 6.3.4.3, 7.2.2, and 7.2.3.

5) In 6.3.1, the punch velocity range was expanded and permission for exceptional cases in aluminium alloys, as well as steel, was added.

6) Clarification was added that although the Nakajima method is known to have non-linear strain paths (6.3.3.1), it is still acceptable. Clarification as to why the failure is required to be near the apex of the dome was added to 6.3.3.3. In 6.3.3.3, the “validity of test” requirement for the Nakajima test was made explicit in a similar format to that shown for the Marciniak test in 6.3.4.4. In 6.3.3.3 and 6.3.4.4, a statement regarding rejection of specimens not meeting the valid test requirements was added.

7) The “Measuring instrument” clause (4.3.5 in the previous edition) was removed since it is a repetition of the “Measurement instrument” section of 6.3.2 but had a different accuracy requirement. The required accuracy is now shown as originally described in 6.3.2.

8) The requirement on the second derivative range was clarified in 7.2.3(c), and the requirements in the keys of Figures 8 and 9 were changed to match 7.2.3(c).

9) The permission to use other methods of measurement was moved from 7.2.1 to 7.1 and was clarified.

10) The statement regarding the “time-dependent method” was removed from 7.1 but now a statement admitting the use of other methods including both the “time-dependent method” or “time and position dependent methods” appears in Clause 5.

11) In 7.2.2, the method of selecting the section line locations based on the crack position was clarified, and permission was added to use the maximum strain location, as long as the test validity requirements are still met.

12) The use of the procedure in 7.2.3 when extracting the “bell-shaped curve” for use in evaluating the section lines using the position-dependent method has been changed to being required rather than just suggested. This seems to be consistent with the original intent.

13) In Annex A, the method was changed to be required rather than proposed. Annex C was clarified to show that the procedure is required. Clarification to the text of Annex D was added, and its use is explicitly permitted. In Annex F, explicit permission to use a regression using in-house functions was added, as well as the requirement that the function be reported.

14) Editorial changes and clarifications were made throughout the document.

A list of all parts in the ISO 12004 series can be found on the ISO website.

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.

Introduction

A forming-limit diagram (FLD) is a diagram containing major/minor strain points.

An FLD can distinguish between safe points and necked or failed points. The transition from safe to failed points is defined by the forming-limit curve (FLC).

To determine the forming limit of materials, two different methods are possible.

1) Strain analysis on failed press shop components to determine component and process dependent FLCs.

   In the press shop, the strain paths followed to reach these points are generally not known. Such an FLC depends on the material, the component, and the chosen forming conditions. This method is described in ISO 12004-1 and is not intended to determine one unique FLC for each material.

2) Determination of FLCs under well-defined laboratory conditions.

   For evaluating formability, one unique FLC for each material in several strain states can be measured. The determination of the FLC must be specific and uses multiple linear strain paths. This document, i.e. ISO 12004-2, is intended for this type of material characterization.

For this document (concerning determination of forming-limit curves in laboratory), the following conditions are also of note.

— Forming-limit curves (FLCs) are determined for specific materials to define the extent to which they can be deformed by drawing, stretching or any combination of drawing and stretching. This capability is limited by the occurrence of localized necking and/or fracture. Many methods exist to determine the forming limit of a material; but results obtained using different methods cannot be used for comparison purposes.

— The FLC characterizes the deformation limit of a material in the condition after a defined thermo-mechanical treatment and in the analysed thickness. For a judgement of formability, the additional knowledge of mechanical properties and the material's history prior to the FLC-test are important.

To compare the formability of different materials, it is important to judge not only the FLC but also the following parameters:

a) mechanical properties at least in the main direction;

b) percentage plastic extension at maximum force, according to ISO 6892-1;

c) *r*-value with given deformation range, according to ISO 10113;

d) *n*-value with given deformation range, according to ISO 10275.

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Part 2: Determination of forming-limit curves in the laboratory

1 Scope

This document specifies testing conditions for use when constructing a forming-limit curve (FLC) at ambient temperature and using linear strain paths. The material considered is flat, metallic and of thickness between 0,3 mm and 4 mm.

NOTE The limitation in thickness of up to 4 mm is proposed, giving a maximum allowable thickness to the punch diameter ratio.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

Table 1 — Symbols

Symbol	English	French	German	Unit
e	Engineering strain	Déformation conventionnelle	Technische Dehnung	%
ε	True strain (logarithmic strain)	Déformation vraie (déformation logarithmique)	Wahre Dehnung (Umformgrad, Formänderung)	—
ε_1	Major true strain	Déformation majeure vraie	Grössere Formänderung	—
ε_2	Minor true strain	Déformation mineure vraie	Kleinere Formänderung	—
ε_3	True thickness strain	Déformation vraie en épaisseur	Dickenformänderung	—
σ	Standard deviation	Ecart-type	Standardabweichung	—
D	Punch diameter	Diamètre du poinçon	Stempeldurchmesser	mm
D_{bh}	Carrier blank hole diameter	Diamètre du trou du contre-flan	Lochdurchmesser des Trägerblechs	mm
X(0), X(1) X(m) ....X(n)	X-position	Position en X	X-Position	mm

