
**Metallic materials — Sheet and strip
— Determination of biaxial stress-
strain curve by means of bulge test
with optical measuring systems**

*Matériaux métalliques — Tôles et bandes — Détermination de
la courbe contrainte-déformation biaxiale au moyen de l'essai de
gonflement hydraulique avec systèmes de mesure optiques*



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Published in Switzerland

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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).

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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 16808:2014), of which it constitutes a minor revision. The changes are as follows:

- the designation of $r_{1_{100}}$ in [Table 1](#) has been modified;
- the title of [Figure A.4](#) has been modified;
- [Formula \(B.2\)](#) has been modified;
- Annex A has been deleted and other annexes have been renumbered accordingly;
- the status of [Annex A](#) (formerly Annex B) has been changed to informative;
- minor editorial changes have been made to align with ISO/IEC Directives Part 2, 2021.

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.

Metallic materials — Sheet and strip — Determination of biaxial stress-strain curve by means of bulge test with optical measuring systems

1 Scope

This document specifies a method for determination of the biaxial stress-strain curve of metallic sheets having a thickness below 3 mm in pure stretch forming without significant friction influence. In comparison with tensile test results, higher strain values can be achieved.

NOTE In this document, the term "biaxial stress-strain curve" is used for simplification. In principle, in the test the "biaxial true stress-true strain curve" is determined.

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 terminology 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 and abbreviated terms

The symbols and designations used are given in [Table 1](#).

Table 1

Symbol	Designation	Unit
d_{die}	Diameter of the die (inner)	mm
d_{BH}	Diameter of the blank holder (inner)	mm
R_1	Radius of the die (inner)	mm
h	Height of the drawn blank (outer surface)	mm
t_0	Initial thickness of the sheet (blank)	mm
t	Actual thickness of the sheet	mm
p	Pressure in the chamber	MPa
rms	Standard deviation (root mean square)	-
ρ	Radius of curvature	mm
r_1	Surface radius for determining curvature	mm
r_2	Surface radius for determining strain	mm
r_{1_100}	Surface radius to determine curvature with a diameter of 100 mm	mm
a_i, b_i	Coefficients for response surface	-

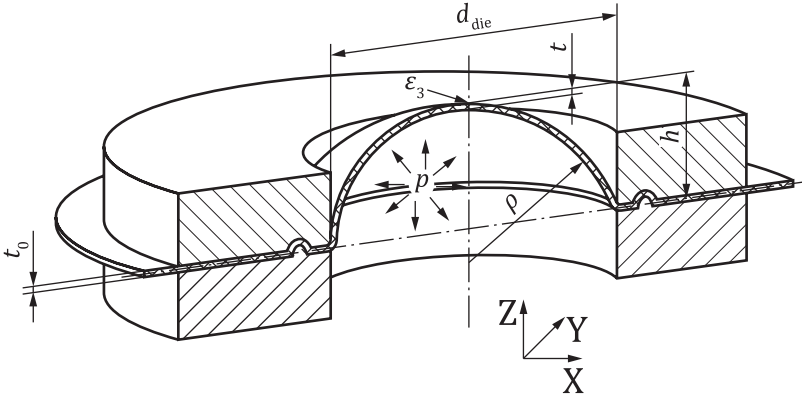
Table 1 (continued)

Symbol	Designation	Unit
σ_B	Biaxial stress	MPa
e	Engineering strain	-
ε_1	Major true strain	-
ε_2	Minor true strain	-
ε_3	True thickness strain	-
ε_E	Equivalent true strain	-
l_s	Coordinate and length of a section	mm
dz	Displacement in the z-direction	mm
dz_{mv}	Displacement after movement correction	mm

5 Principle

A circular blank is completely clamped at the edge in a tool between die and blank holder. A bulge is formed by pressing a fluid against the blank until final fracture occurs (Figure 1). During the test, the pressure of the fluid is measured and the evolution of the deformation of the blank is recorded by an optical measuring system[1],[2],[3]. Based on the recorded deformation of the blank, the following quantities near the centre of the blank are determined: the local curvature, the true strains at the surface, and, by assuming incompressible deformation of the material, the actual thickness of the blank. Furthermore, assuming the stress state of a thin-walled spherical pressure vessel at the centre of the blank, the true stress is calculated from the fluid pressure, the thickness and the curvature radius.

NOTE In addition to the bulge test procedures with optical measurement systems introduced in Reference [1] and described in the following, there are also laser systems[4],[5],[6] or tactile systems[7],[8],[9] valid for bulge test investigation, which are not covered in this document.



- Key**

 - h height of the drawn blank (outer surface)
 - p pressure in the chamber
 - ε_3 true thickness strain (at the apex of the dome)
 - d_{die} diameter of the die (inner)
- ρ radius of curvature
 - t_0 initial thickness of the sheet (blank)
 - t actual thickness of the sheet

Figure 1 — Principle of the bulge test

The coordinate origin shall be in the centre of the blank holder. The XY-plane should be parallel to the surface of the blank holder (parallel to the clamped metal sheet before forming). Herein, the x-direction corresponds to the rolling direction. The z-direction shall be normal to the clamped metal sheet before forming, with the positive direction towards the optical sensor.