INTERNATIONAL STANDARD

# ISO 12004-1

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# Metallic materials — Sheet and strip — Determination of forming-limit curves —

## Part 1:
## Measurement and application of forming-limit diagrams in the press shop

*Matériaux métalliques — Tôles et bandes — Détermination des courbes limites de formage —*

*Partie 1: Mesurage et application des diagrammes limites de formage dans les ateliers d'emboutissage*

Reference number
ISO 12004-1:2008(E)

# Contents

Page

## Foreword

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

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12004-4 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

This first edition of ISO 12004-1, together with ISO 12004-2, cancels and replaces ISO 12004:1997 which has been technically revised.

ISO 12004 consists of the following parts, under the general title *Metallic materials — Sheet and strip — Determination of forming-limit curves*:

— *Part 1: Measurement and application of forming-limit diagrams in the press shop*

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

## Introduction

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

An FLD can distinguish between safe 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 of failed press shop components to determine component and process dependent FLCs:

   In the press shop, strain paths 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 this part of ISO 12004.

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

   For evaluating formability, one unique FLC for the defined material is necessary. The determination of FLC has to be specific and it is necessary to use different linear strain paths. This method should be used for material characterization as described in ISO 12004-2.

# Metallic materials — Sheet and strip — Determination of forming-limit curves —

# Part 1:
# Measurement and application of forming-limit diagrams in the press shop

## 1 Scope

This part of ISO 12004 provides guidelines for developing forming-limit diagrams and forming-limit curves for metal sheets and strips of thicknesses from 0,3 mm to 4 mm.

## 2 Symbols and abbreviated terms

The symbols used in forming-limit diagrams are specified in Table 1, and examples of grid patterns used are given in Annex B.

**Table 1 — Symbols and definitions**

| Symbol | Definition | Unit |
|---|---|---|
| $t_o$ | Thickness of test piece | mm |
| $l_0$ | Original gauge length of grid pattern | mm |
| $l_1$ | Final length in major strain direction | mm |
| $l_2$ | Final length at 90° to major strain direction | mm |
| $e$ | Engineering strain | % |
| $e_1$ | Major engineering strain | % |
| $e_2$ | Minor engineering strain (90° to major) | % |
| FLD | Forming-limit diagram | — |
| FLC | Forming-limit curve | — |

## 3 Principle

A pattern of precise gauge lengths of appropriate size is applied to the flat surface of a metal sheet test piece, then the test piece is formed until fracture, and the percent change in the gauge length in the major direction and in the minor strain direction at 90° to this is measured in order to determine the forming-limit under the imposed strain conditions. A number of repeated tests under varying strain conditions are carried out to provide data for the forming-limit curve (FLC) for the material when these limiting strains are plotted on the forming-limit diagram (FLD) (see Figure 1).

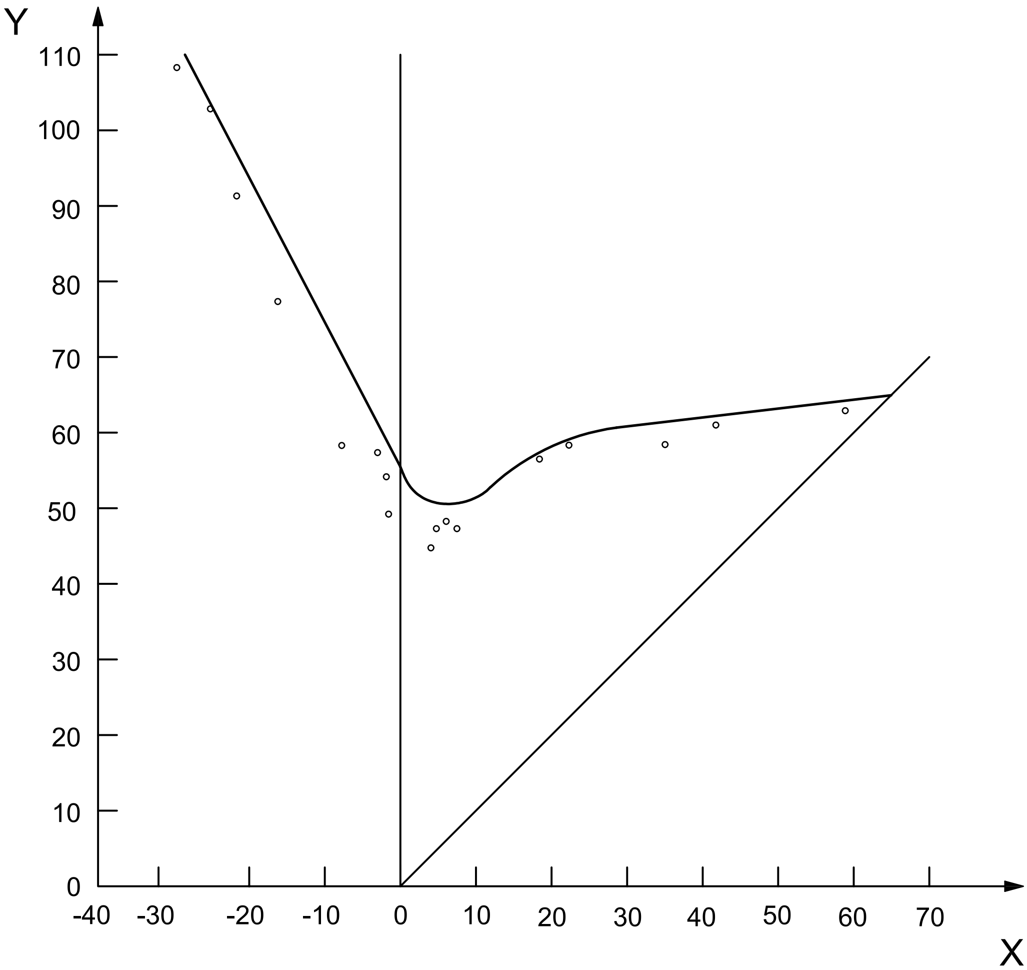
## 4 Test conditions

**4.1** Gauge lengths in the range of 1,5 mm to 5,0 mm are recommended. The actual gauge lengths shall be known to within ± 2 %.

**4.2** During the forming of test pieces, the strain in the critical area shall be uniform before onset of necking.

**4.3** In order to achieve this, any set of tooling employing a holding force and a deformation force may be used to develop the limiting strain condition.

**4.4** The forming-limit curve shall be plotted on the forming-limit diagram. Figure 1 shows an example of a forming-limit curve.




**Key**

X minor strain, in percent

Y major strain, in percent

**Figure 1 — Typical forming-limit curve**

## 5 Procedure

**5.1** The recommended procedure for the determination of the forming limit is as follows.

**5.1.1** Take a representative sample of the material to be evaluated.

**5.1.2** Apply a suitable grid pattern, that has been checked for accuracy of the initial gauge lengths, to the surface of a test piece in areas of the part to be formed which are known, or have been established by investigation, to be critical.

**5.1.3** Any test device that satisfies Clause 4 may be used to form the test piece, such as a universal tensile testing machine, a stamping press, a cupping press, a hydraulic bulge machine and their combinations or any other equipment capable of clamping the test piece and applying a plastic deformation force in an area remote from the edge. A universal testing machine may be employed and forming limits established using a tensile test.

**5.1.4** Test pieces shall be tested while clamped around the whole of their periphery, or shall be cut into strips of varying widths to give a range of strain conditions. The surface between the punch and the specimen shall be suitably lubricated using a standard product for the operation. A combination of polyethylene sheet and lubricant can be used.

**5.1.5** Stop the test at the first occurrence of fracture.

**5.1.6** Determine the strains $e_1$ and $e_2$ as follows.

**5.1.7** Measure three adjacent gauge lengths in the direction of $e_1$ that were originally in a straight line. Repeat until the three values obtained are the same to within ± 10 %. Record the average of these three values as $l_1$.

NOTE A more accurate method may be prescribed as mentioned in ISO 12004-2.

**5.1.8** If it is not possible to obtain three values within ± 10 %, form a new test piece and repeat the measurements.

**5.1.9** Select one of the gauge lengths measured in 5.1.7 and measure the gauge length at 90° to the original $e_1$ direction, and report this as $l_2$.

**5.2** Calculate the percent strains $e_1$ and $e_2$ as follows:

$$e_1 = \frac{l_1 - l_0}{l_0} \times 100 \quad (1)$$

$$e_2 = \frac{l_2 - l_0}{l_0} \times 100 \quad (2)$$

**5.3** Make measurements on a sufficient number of test pieces to plot a forming-limit curve.

## 6 Interpretation of results

**6.1** Plot $e_1$ against $e_2$ on a forming-limit diagram. As shown in Figure 1, the major strain $e_1$ is plotted along the Y-axis and the minor strain $e_2$ is plotted along the X-axis.

**6.2** Draw the forming-limit curve through the points of maximum $e_1$ strain (see Figure 1).

**6.3** The effect of a forming operation on a particular part may be estimated from the diagram by measuring the strains in critical areas and comparing the results with the curve for the material used.

## 7 Test report

**7.1** The test report shall include the following information:

a) a reference to this part of ISO 12004;

b) the identification of the test piece;

c) the thickness of the test piece;

d) the forming-limit curve (FLC) plotted on the forming-limit diagram (FLD) (as shown in Figure 1);

e) the gauge length of the grid pattern used;

f) lubrication conditions.

**7.2** The test report may also include the following information:

a) selected mechanical properties of the material tested;

b) the chemical composition (percentage content of major elements) of the material tested;

c) a description of the procedure used;

d) the type of grid pattern used;

e) details of any deviation from the procedure specified (see, in particular, Annex A).

# Annex A
(informative)

# Modification to forming-limit curves

To accommodate the variations experienced in the production of a given commercial product and to allow corrections to be made for known differences, such as the different behaviour of similar materials of different thicknesses when formed using the same tooling, or different strain-hardening characteristics, modifications have been proposed to the forming-limit curve. These modifications displace the curve upwards for thicker materials and for materials with a higher strain hardening exponent ($n$-value) (see ISO 10275). Such modifications to FLCs have not been established as viable corrections and, if employed, shall be specifically noted in the test report.

Figure 1 shows an example of an FLC. Deformed areas in a formed part which have strains lying above or close below, the FLC are likely to fail and should be examined to reduce strain, or a material with a higher FLC should be used.

# Annex B
(informative)

# Examples of grid patterns currently in use

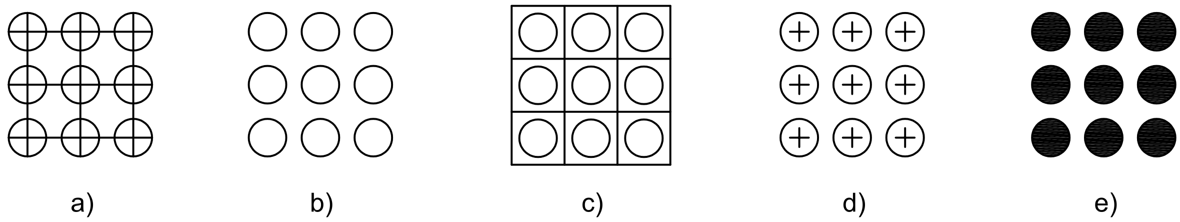



**Figure B.1 — Examples of various types of circular grid patterns**

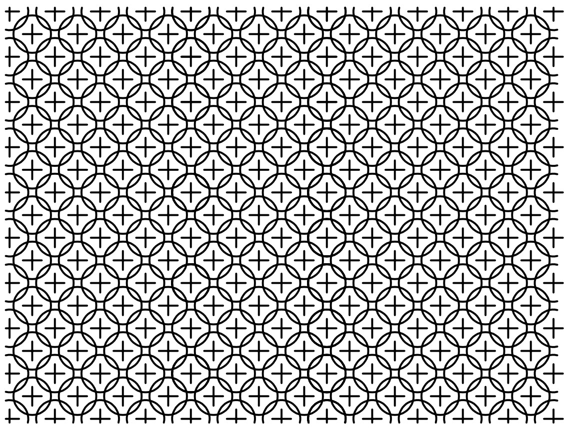


**Figure B.2 — Example of a circular grid pattern**

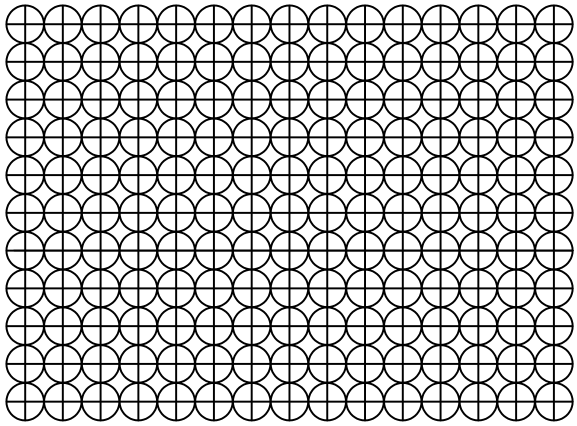


**Figure B.3 — Example of a circular grid pattern**

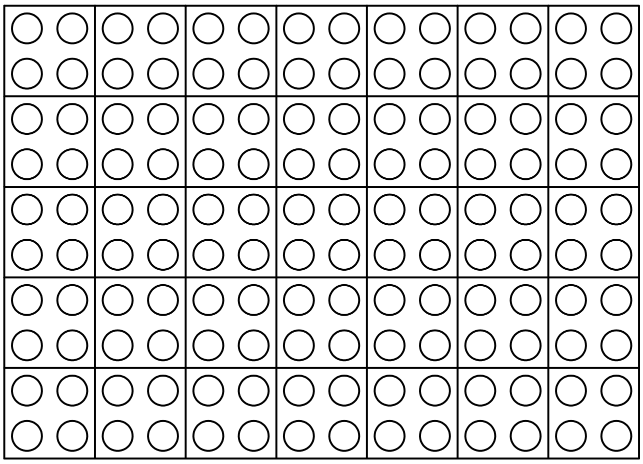


**Figure B.4 — Example of a circular grid pattern in squares**

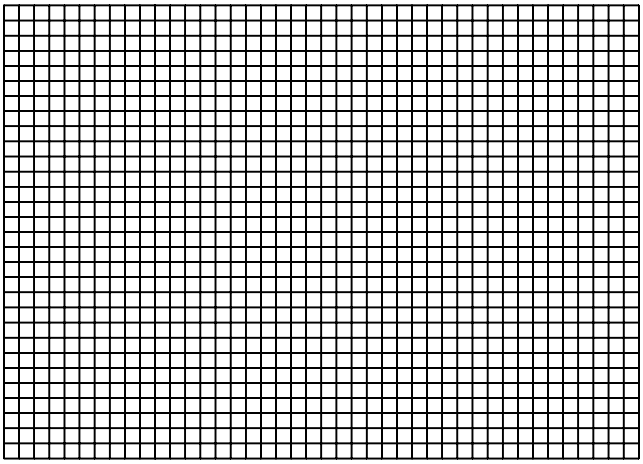


**Figure B.5 — Example of a square grid pattern**

# Bibliography

[1] ISO 10275, *Metallic materials — Sheet and strip — Determination of tensile strain hardening exponent*

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