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Metallic materials — Sheet and strip — Biaxial tensile testing method using a cruciform test piece

Matériaux métalliques — Tôles et bandes — Méthode d'essai de traction biaxiale sur éprouvette cruciforme

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Foreword

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The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee 2, *Ductility testing*.

Introduction

This International Standard specifies the testing method for measuring the biaxial stress-strain curves of sheet metals subject to biaxial tension at an arbitrary stress ratio using a cruciform test piece made of flat sheet metals. The International Standard applies to the shape and strain measurement position for the cruciform test piece. The biaxial tensile testing machine is described in Annex C, only in terms of the typical example of the machine and the requirements that the machine should comply with.

The cruciform test piece recommended in this International Standard has the following features:

a) the gauge area of the test piece ensures superior homogeneity of stress, enabling measurement of biaxial stress with satisfactory accuracy;

b) capability of measuring the elasto-plastic deformation behaviour of sheet metals at arbitrary stress or strain rate ratios;

c) free from the out-of-plane deformation as is encountered in the hydrostatic bulge testing method;

d) easy to fabricate from a flat metal sheet by laser cutting, water jet cutting, or other alternative manufacturing methods.

Metallic materials — Sheet and strip — Biaxial tensile testing method using a cruciform test piece

1 Scope

This International Standard specifies the method for measuring the stress-strain curves of sheet metals subject to biaxial tension using a cruciform test piece fabricated from a sheet metal sample. The applicable thickness of the sheet shall be 0,1 mm or more and 0,08 times or less of the arm width of the cruciform test piece (see Figure 1). The test temperature shall range from 10 °C to 35 °C. The amount of plastic strain applicable to the gauge area of the cruciform test piece depends on the force ratio, slit width of the arms, work hardening exponent (*n*-value) (see Annex B), and anisotropy of a test material.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 80000-1, *Quantities and units — Part 1: General*

3 Terms and definitions

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

3.1
cruciform test piece
test piece which is recommended in the biaxial tensile test and whose geometry is specified in this International Standard (see Figure 1)

3.2
gauge area
square area which is located in the middle of the cruciform test piece and is enclosed by the four arms of the cruciform test piece (see Figure 1)

3.3
arm
generic name for all areas other than the gauge area in the cruciform test piece. The arms play a role of transmitting tensile forces in two orthogonal directions to the gauge area of the cruciform test piece (see Figure 1)

3.4
biaxial tensile testing machine
testing machine for applying biaxial tensile forces to a cruciform test piece in the orthogonal directions parallel to the arms of the test piece (see Annex C)

3.5
yield surface
a group of stress determined in a stress space, at which a metal starts plastic deformation when probing from the elastic region into the plastic range[1] (see Annex A)

3.6
yield function
mathematical function used to generate the conditional equation (yield criterion) which the stress components should comply with when the material subject to the stress is in the plastic deformation state (see Annex A)

3.7
contour of plastic work
graphic figure derived by subjecting the material to plastic deformation along various linear stress paths and plotting the stress points in stress space at the instance when the plastic work consumed per unit volume along each stress path becomes identical; and the plotted stress points are approximated into either a smooth curve or curved surface (see Annex A)

4 Principle

Measurement is made at room temperature, on the yield stress and the stress-strain curves of sheet metals under biaxial tensile stresses by measuring simultaneously and continuously the biaxial tensile forces and strain components applied to the gauge area of a cruciform test piece while applying biaxial tensile forces in the orthogonal directions parallel to the arms of the test piece. The test piece is made of a flat sheet metal and has a uniform thickness. The measured biaxial stress-strain curves are used to determine contours of plastic work of the sheet samples (see Annex A). According to the finite element analyses of the cruciform test piece as recommended in Clause 5 and the strain measurement position as specified in Clause 6.2.4, the stress calculation error is estimated to be less than 2,0 %.[2][3]

5 Test piece

5.1 Shape and dimensions

Figure 1 shows the shape and dimensions of the cruciform test piece recommended in this International Standard. The test piece shall be as described below.

a) In principle, the thickness of a test piece, a, shall be the same as that of the as-received sheet sample, without any work done in the thickness direction. See 5.1 b) for an exception to the rule.

b) The arm width, B, should be 30 mm or more, except that it can be determined according to the agreement between parties involved in transaction. It shall satisfy $a \leq 0{,}08B$ and should be accurate to within ± 0,1 mm for all four arms. The sheet thickness can be reduced to satisfy $a \leq 0{,}08B$ according to the agreement between parties involved in transaction.

c) Seven slits per one arm shall be made. Specifically, one slit shall be made on the centerline (x-axis or y-axis) of the test piece with a positional accuracy of ± 0,1 mm, and three slits shall be made at an interval of $B/8$ with an positional accuracy of ± 0,1 mm on each side of the centerline. All slits shall have the same length, L, and should be accurate to within ±0,1 mm. The relationship of $B \leq L \leq 2B$ should be established. The opposing slit ends shall be made at an equal distance, $B_{Sx}/2$ and $B_{Sy}/2$, from the centerline with a positional accuracy of $B/2$ ± 0,1 mm.

d) The slit width, w_S, should be made as small as possible (see Figure B.2), preferably less than 0,3 mm.

e) The grip length, C, is considered to be enough if it can secure the test piece to the grips of the biaxial tensile testing machine and can transmit the necessary tensile force to the test piece. The standard grip length would be $B/2 \leq C \leq B$, but can be determined arbitrarily according to the agreement between parties involved in transaction.

f) An alternative test piece geometry can be used. In the use of the alternative cruciform test pieces, the evidence of the stress measurement accuracy has to be clarified between the contractual partners.

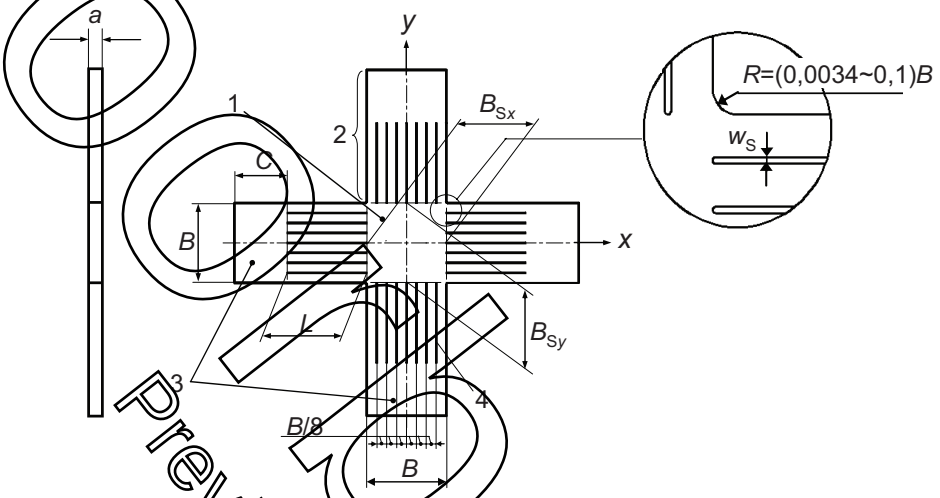
5.2 Preparation of the test pieces

a) The permitted variations in thickness and the permitted variations from a flat surface of the sheet metal sample from which the cruciform test pieces are taken shall be in accordance with relevant product standards or national standards.

b) The standard sampling direction of the test piece shall be such that the directions of arms are parallel to the rolling (x) and transverse (y) directions of the sheet sample, respectively. The test piece sampling direction can be determined according to the agreement between parties involved in transaction.

c) For the fabrication of the test piece (including making of slits), any method, e.g. laser cutting, water jet cutting, or other alternative manufacturing methods, demonstrated to work satisfactorily can be used if agreed upon by the parties.

d) Unless otherwise specified and except for the sampling work, unnecessary deformation or heating to the test piece shall be avoided.



Key

1 gauge area
2 arm
3 grip
4 slit
a thickness of a test piece
B arm width
B_{Sx} distance between opposing slit ends in the x direction
B_{Sy} distance between opposing slit ends in the y direction
C grip length
L slit length
R corner radius at the junctions of arms to the gauge area
w_S slit width

Figure 1 — Standard shape and dimensions of the recommended cruciform test piece[2][3]

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