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Mechanical joining of sheet materials — Destructive testing of joints — Specimen dimensions and procedure for mechanized peel testing of single joints

Assemblage mécanique de tôles — Essais destructifs des assemblages — Dimensions des échantillons et procédure pour l'essai de pelage mécanisé des assemblages simples

Reference number
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Foreword

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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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This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding and allied mechanical joining*.

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Mechanical joining of sheet materials — Destructive testing of joints — Specimen dimensions and procedure for mechanized peel testing of single joints

1 Scope

This document specifies the geometry of test specimens and the testing procedure for mechanized peel testing of single mechanical joints on single-lap test specimens up to a single sheet thickness of 4,5 mm.

The term "sheet", as used in this document, includes extrusions and cast materials.

The purpose of the mechanized peel tests is to determine the mechanical characteristics and the failure modes of the joints made with different joining methods.

This document does not apply to civil engineering applications such as metal buildings and steel constructions which are covered by other application standards.

NOTE For mechanized peel testing of resistance spot, seam and embossed projection welds, see ISO 14270

2 Normative references

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.

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

3 Terms and definitions

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

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/

3.1
mechanized peel strength
MPS
F_{max}
maximum *peel force* (3.2) obtained from mechanized peel testing

3.2
peel force
F
force/load which is applied to the test specimen during mechanized peel testing

3.3
slippage force
F_{sl}
peel force (3.2)/load at which slippage occurs if the phenomenon is observed during testing

3.4
specimen deformation
s
crosshead displacement during testing

3.5
specimen deformation at maximum load
$s_{F\text{max}}$
specimen deformation (3.4) at which the maximum *peel force* (3.2)/load F_{max} is recorded

Note 1 to entry: See Figure 4 and Figure 5

3.6
specimen deformation at 0,3 F_{max}
$s_{0,3F\text{max}}$
specimen deformation (3.4) at which 0,3F_{max} is recorded

Note 1 to entry: See Figure 4 and Figure 5

3.7
specimen deformation at fracture
s_{fracture}
specimen deformation (3.4) of at which fracture occurs

Note 1 to entry: See Figure 4 and Figure 5

3.8
dissipated energy
W
amount of energy dissipated until a displacement point under the load-crosshead displacement curve

[SOURCE: ISO 12161:2006, 3.4.1]

3.9
dissipated energy up to F_{max}
$W_{F\text{max}}$
dissipated energy or work calculated by integrating the area under the crosshead displacement curve up to the point at which maximum peal load (MPS point) is recorded

$$W_{F\,\text{max}} = \int_0^{s_{F\,\text{max}}} F\ ds$$

3.10
dissipated energy up to 0,3 F_{max}
$W_{0,3F\text{max}}$
dissipated energy or work calculated by integrating the area under the crosshead displacement curve up to the point where the peel force drops to 30 % of the MPS value, F_{max}

$$W_{0,3F\,\text{max}} = \int_0^{s_{0,3F\,\text{max}}} F\ ds$$

Note 1 to entry: See Clause 6

3.11
dissipated energy up to fracture
W_{fracture}

dissipated energy calculated by integrating the crosshead displacement curve up to the point at which fracture occurs

$$W_{fracture} = \int_0^{s_{fracture}} F \ ds$$

4 Test pieces and test specimens

Table 1 and Figure 1 give the dimensions and form of test coupons and test specimens for mechanized peel testing, and the location of mechanical joint. The positional accuracy of the mechanical joints on the test specimen shall be ± 1 mm in every direction.

Table 1 — Test specimen dimensions and joint position

Dimensions in millimetres

Thickness t	**Flange length** a	**Specimen width** b	**Coupon length** [a] l_s	**Free length between clamps** [a] l_f	**Edge distance** e
$0,5 < t \leq 4,5$	50	50	100	30	25
			≥160	105	

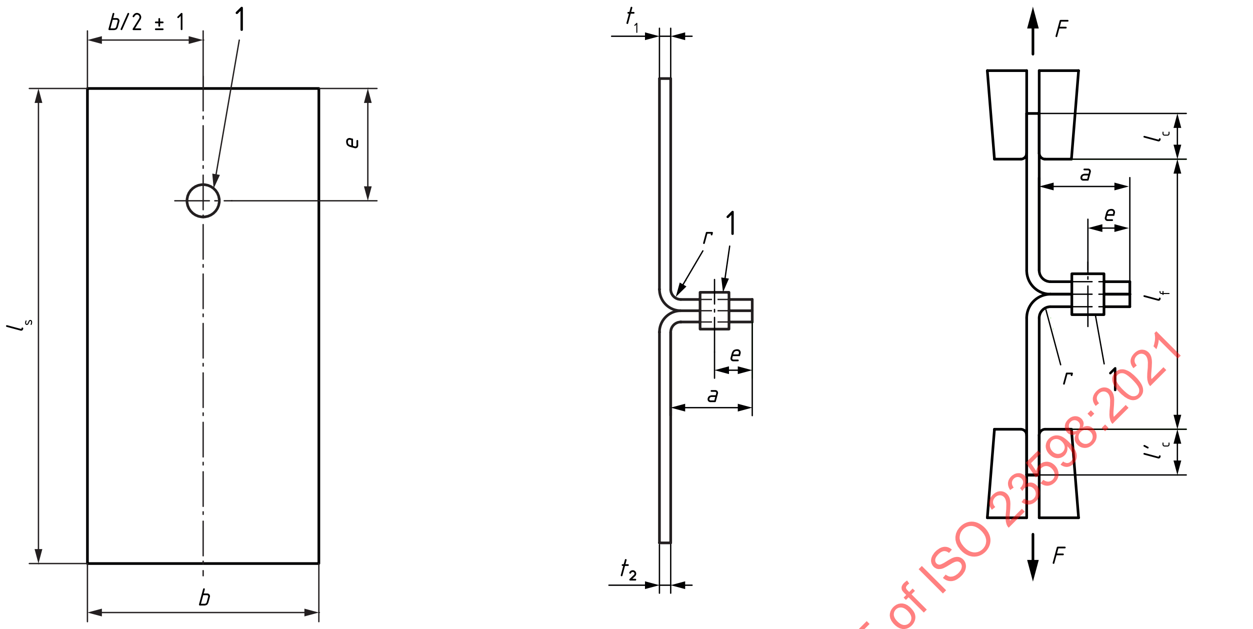
[a] The shorter coupon length (before joining) is preferred but a longer specimen can be needed based on joining process limitations or for comparison with results from testing in accordance with ISO 14270.

The test specimen for mechanical joints shall be produced as a single joint specimen as shown in Figure 1 b), which is made of two coupons shown in Figure 1 a), and then the mechanized peel test specimen shall be mounted on a tensile test machine as shown in Figure 1 c).

In the case of unequal sheet thicknesses, the test specimen dimensions shall be based on the thinner sheet. Mechanized peel testing shall be made by the procedure specified in Clause 5 and Clause 6.

The tolerances on the dimensions shall be in accordance with Table 2.

Dimensions in millimetres



a) **Test coupons**

b) **Test specimen**

c) **After clamped by a testing machine**

Key

1	joint/fastener	a	flange length
l_s	coupon length	r	bending radius
l_f	free length between clamps	b	coupon/specimen width
l_c, l'_c	clamping length	e	edge distance
F	applied force (load)		

Figure 1 — Test coupons, test specimens and the clamping state for mechanized peel testing

Table 2 — Tolerances on dimensions for mechanized peel test specimens

Dimensions in millimetres

Flange length a	**Coupon/ specimen width** b	**Edge distance** e	**Coupon length** l_s	**Free length between clamps** l_f	**Bend radius** r
$^{+1,0}_{0}$	$^{+1}_{0}$	$^{+0,5}_{0}$	$^{0}_{-1}$	$^{0}_{-1}$	± 0,5t[a]
[a] t is the sheet thickness of each coupon.					

5 Preparation of mechanized peel test specimens

5.1 General

The mechanized peel test specimens for mechanical joints are recommended to be made in the following sequence, so that the test specimens can be tested using a tensile test machine;

Bending ⟶ Mechanical joining ⟶ Mechanized peel testing

The sequence is called “joining-after-bending process”.

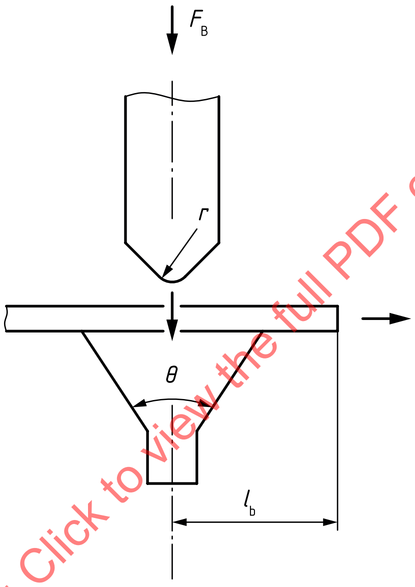
NOTE In resistance spot welding, the bending-after-welding process (Joining ⟶ Bending ⟶ Mechanized peel testing) can be used, but in the case of mechanical joining, some fasteners cannot be tested using this sequence as the fastener interferes with the clamping face for bending after joining, or the clamping device can influence the joint part properties.

5.2 Bending procedure for preparation of peel test specimens

The test coupons shall be bent before mechanical joining as shown in Figure 2.

The recommended set-up conditions of jigs for bending with a press brake are shown in B.1.

NOTE When setting the value $l_b = a$ as shown in Figure 2, the maximum error in the flange length is less than ±0,5 mm if $r = 2t$ and $t \leq 4,5$ mm (see detail in Annex C).



Key

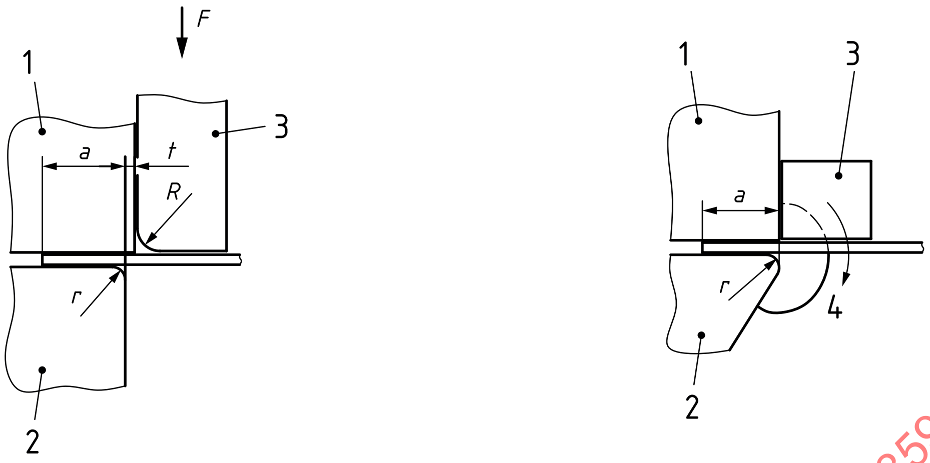
F_B bending force

l_b centre of bending (= a, flange length, see Figure 1)

r radius of bent corner/bend radius

θ angle

Figure 2 — Bending process with a press brake for test coupons



a) Using a wiping die

b) Using a cornice brake

Key

1	upper jaw	*F*	force
2	lower jaw	*r*	radius of bent corner
3	die	*R*	edge radius of die
4	rotating	*a*	flange length

Figure 3 — Examples of edge bending

A mechanized press brake system is generally recommended for the bending although a manual press brake can be used to bend test coupons for soft and thinner test pieces. Other bending tools shown in Figure 3 are also applicable to make the test coupons. The wiping die and cornice brake system can be used. An example of edge bending is shown in Annex B.

5.3 Dimensions and accuracy of bent radius

The value of the inner radius, *r*, shall be set so that no large and deep cracking occurs during bending on the inner or outer surfaces of the bent corner. The radius value tested shall be recorded. The inner radius *r*, equal to approximately 2*t* (*t*, plate thickness) is recommended. Tolerances shall be in accordance with Table 2.

If any cracks are visible, with up to ×5 magnification, after bending in accordance with 5.2, new test specimens/coupons with larger inner radii shall be made. The value of the inner radius shall be increased until no cracking occurs on the outer side of the bend.

6 Testing procedure and test equipment

The test specimen is clamped in a tensile testing machine which satisfies the requirements of ISO 7500-1, such that the clamps are at the required distance from one another as shown in Figure 1 c). Force and crosshead displacement shall be measured simultaneously during testing, and the measuring accuracy shall be ±1 %. All tests shall be performed at room temperature until the joint fails.

If a special clamping device is used, the shape and size shall be specified in a joining procedure specification (JPS) document, and recorded.

The crosshead displacement rate of the testing machine shall be equal to 10 mm/min or less, and shall be kept constant during testing.

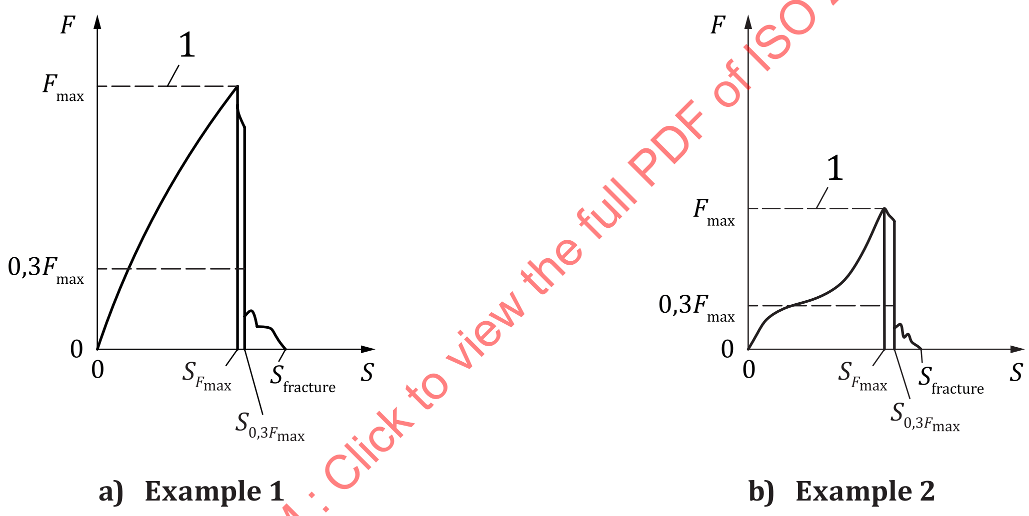
The specimen deformation shall be measured either as the crosshead displacement, or by using an appropriate displacement sensing device directly at the specimen. When using a signal from the crosshead position, it should be corrected for the stiffness of the testing machine. Results can only be compared when performed under similar displacement measuring conditions. The type of measurement and the initial measured length shall be noted in the test report.

The signals for load and specimen deformation during testing shall be recorded as shown in Figure 4, so that at least the peak value of the maximum force is recorded as the MPS in the test report.

NOTE 1 If required, further characteristic data, e.g. $W_{F\max}$, $W_{0,3F\max}$ and W_{fracture}, etc. can be determined from the load-elongation curve (see Figure 4).

Test specimens for mechanized peel testing, as shown in Figure 2b), shall be made with a mechanical joining machine. The recommended set-up conditions of jigs for bending with a press brake are shown in B.1.

NOTE 2 When setting the value $l_b = a$ as shown in Figure 2, the maximum error in the flange length is less than ±0,5 mm if $r = 2t$ and $t \leq 4,5$ mm (see detail in Annex C).



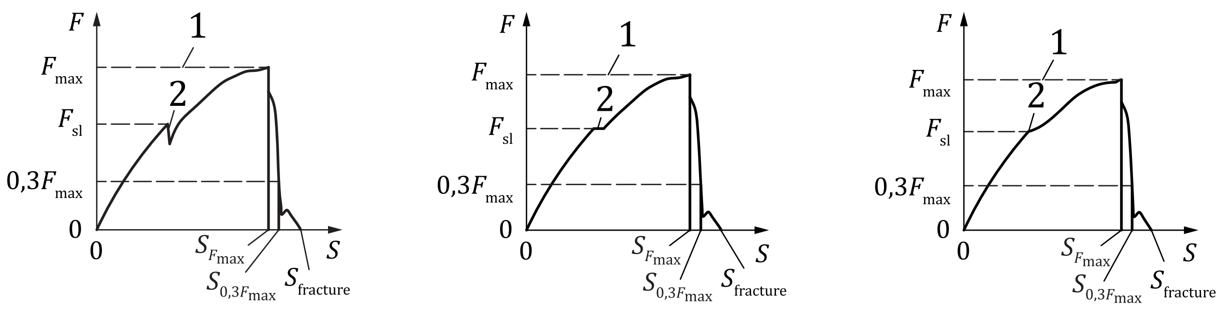
Key

1	mechanized peel strength	$S_{F\max}$	specimen deformation at maximum load
F	load /applied force	$S_{0,3\ F\max}$	specimen deformation at 0,3 $F_{\max}$
s	elongation/crosshead displacement	S_{fracture}	specimen deformation of at which fracture occurs
$F_{\max}$	mechanized peel strength		

Figure 4 — Examples of load-elongation/crosshead displacement curves without slippage (not to scale)

If slippage occurs during the mechanized peel test (See Figure 5), the slippage load is also recorded in the test report.

NOTE 3 If slippage occurs, an accurate calculation of the dissipated energy is not possible with the formulae given in 3.9 to 3.11.



a) Type 1 b) Type 2 c) Type 3

Key

1	mechanized peel strength	F_{sl}	slippage force
2	slippage	S_{Fmax}	specimen deformation at maximum load
F	load/applied force	0,3 F_{max}	specimen deformation at 0,3 F_{max}
F_{max}	mechanized peel strength	$S_{fracture}$	specimen deformation of at which fracture occurs
s	elongation/crosshead displacement		

Figure 5 — Examples of possible slippage recorded on the load-elongation curves (not to scale)

7 Type of failure mode

The type of failure mode after mechanized peel testing shall be classified in accordance with Annex A, and recorded in the test report.

8 Re-test

If fracture occurs only from the bent corner of test specimens during mechanized peel testing in accordance with Clause 6, all mechanized test results shall be disregarded, and new test specimens with larger inner radius shall be made and tested. The value of the inner radius shall be increased until no fracture occurs from the bent part, especially the location of cracks appearing on the bent corner of test specimens. When using larger radii, the radius value tested shall be recorded.

If slippage occurs during the peel test and the slippage load is lower than the required value, re-tests are required with new test specimens after a re-design of the joints, re-selection of the joining technology and/or an improved joining process.

9 Test report

The test report shall contain the following information:

a) a reference to this document (i.e. ISO 23598);

b) name of the examiner and/or the examining body;

c) testing date, location and signature of the examiner and/or the examining body;

d) joining technology/type of joints and description of fasteners used;

e) joining parameters and type of joining equipment;

f) material designation and dimensions of auxiliary materials;

g) material designation of the joints part or the test coupons;

h) the dimensions of the test piece and coupons/specimens;

i) joining direction, stacking order and location of coted sides (if applicable);

j) type of testing equipment and the setting;

k) measuring method of elongation/crosshead displacement;

l) value of bent radius of test coupons;

m) individual values, mean value and standard deviation of the mechanized peel strength;

n) measured diagram obtained by the mechanized peel testing (load – crosshead displacement diagram);

o) individual values, mean value and standard deviation of the characteristic values, e.g. MPS, maximum displacement, slippage force, dissipate energy (if required);

p) failure mode (pull out from bottom sheet, pull out from the fastener head, fastener failure, etc.); and

q) special remarks, if any.

Annex A
(normative)

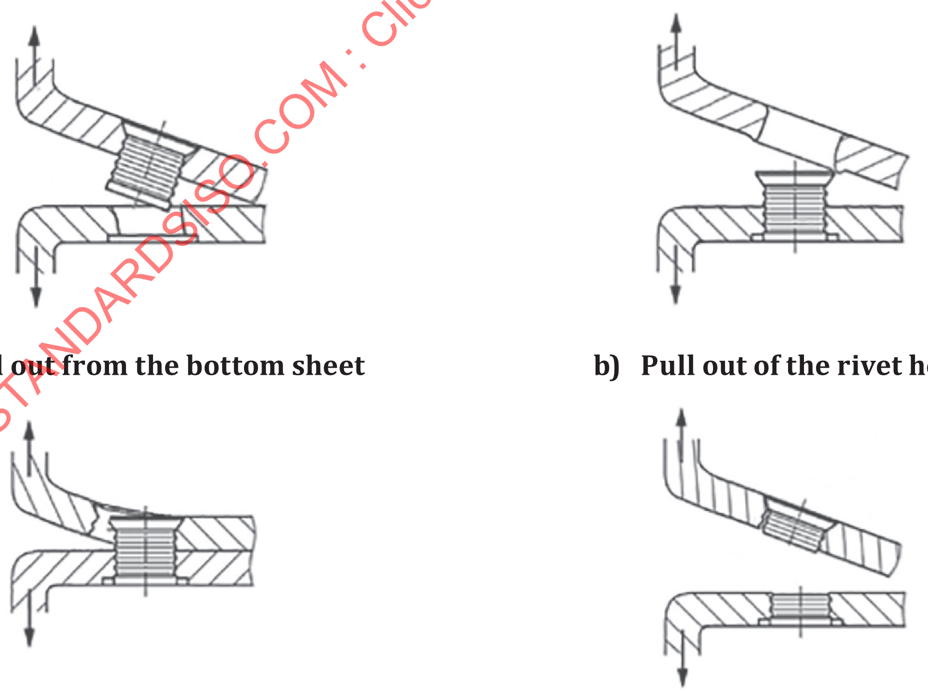
Type of joint failure in mechanized peel testing

Depending on the joining technology, different types of failure can occur. Some of these are specific to the joining technology employed and should be recorded in the test protocol. Typical failure modes for different joints are shown in Figures A.1 to A.7.

In addition to the failure modes shown below, non-permissible sheet separation or deformation may be defined as a failure criterion by the contracting parties.

a) Rivet pull out from bottom sheet **b) Pull out of rivet head** **c) Rivet failure**

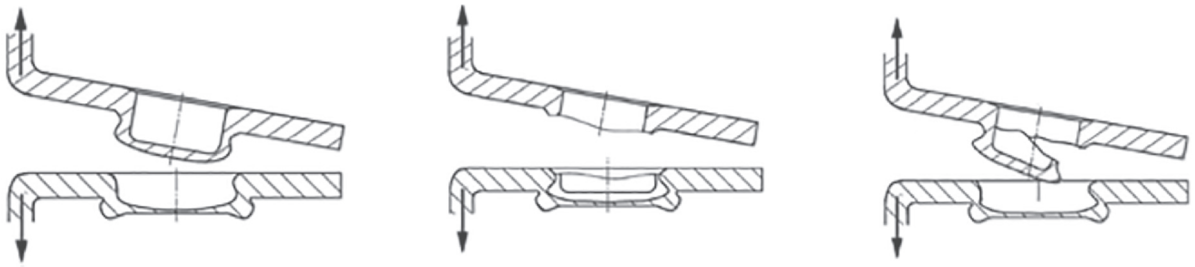
Figure A.1 — Typical failure modes of semi-tubular self-piecing rivet joints



a) Pull out from the bottom sheet **b) Pull out of the rivet head**

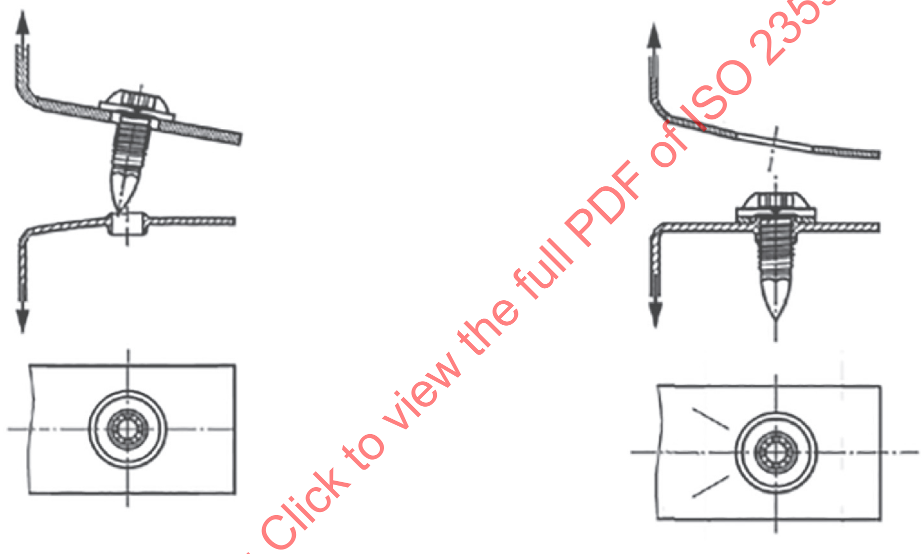
c) Failure of specimen material **d) Rivet failure**

Figure A.2 — Typical failure modes of solid self-piecing rivet joints

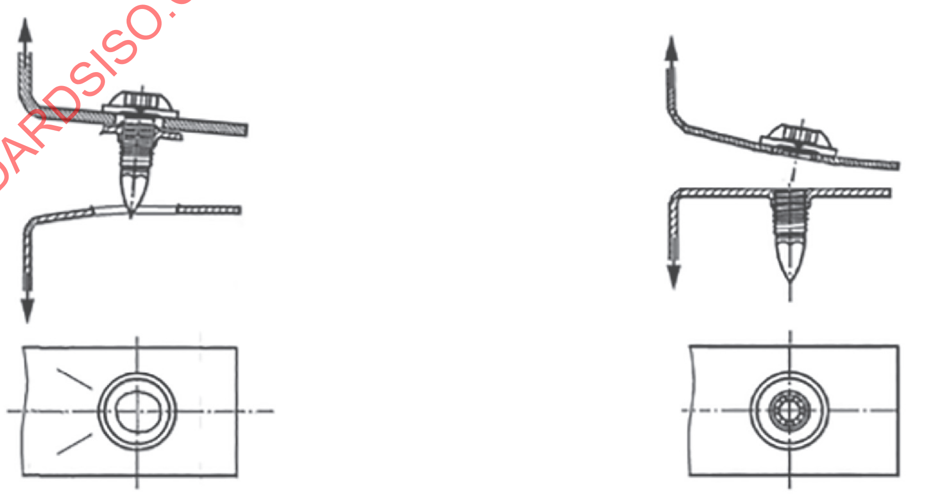


a) Pull out   b) Neck fracture   c) Neck fracture with partial pull out (mixed mode)

Figure A.3 — Typical failure modes of clinch joints



a) Lower sheet thread failure (Sheet thread failure)   b) Sheet material failure (Pull out under screw head)

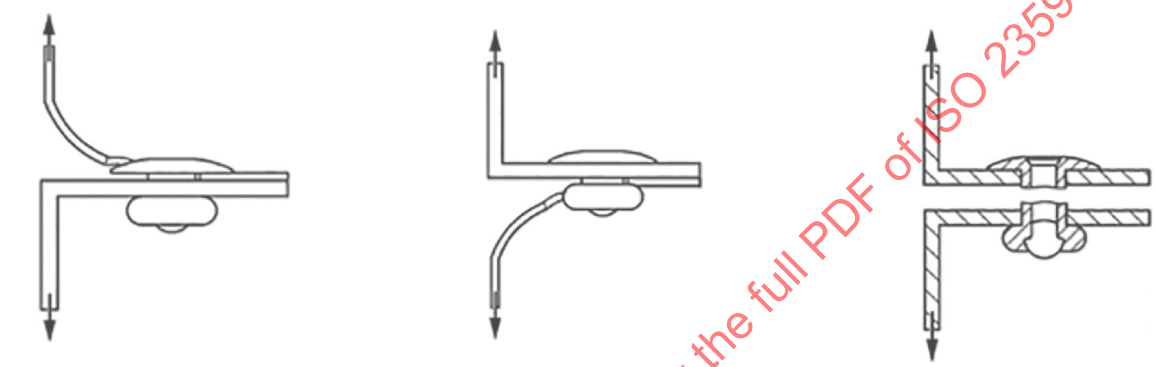


c) Lower sheet pull out   d) Screw failure

Figure A.4 — Examples of failure modes of screwed joints

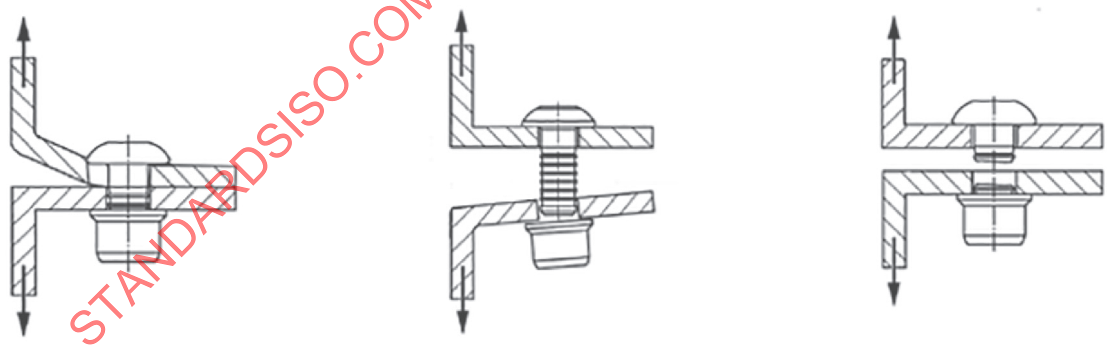
a) **Pull out of weaker sheet material** b) **Shank failure**

Figure A.5 — Typical failure modes of joints made with self-clinching stud



a) **Sheet metal failure (Pull out)** b) **Closed head pull out in lower sheet** c) **Rivet failure**

Figure A.6 — Typical failure modes of blind rivet joints



a) **Sheet material pull out** b) **Bolt collar failure** c) **Bolt failure**

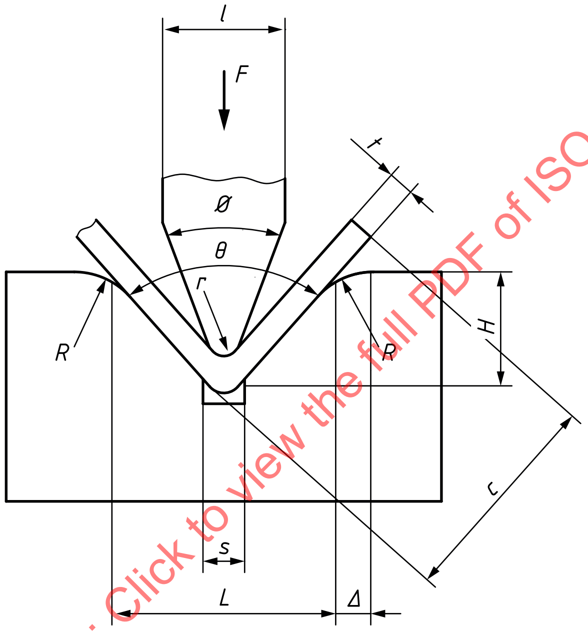
Figure A.7 — Typical failure modes of locked bolt joints

Annex B
(informative)

Examples of bending tools

B.1 Recommended set-up conditions for the bending procedure with a press brake

An example of recommended bending condition is shown in Figure B.1.



Key

$r \approx 2t$

$L = 6t \sim 15t$ (where $L + 2\Delta < 2a$ and a is as per Figure 1)

$l = 0{,}5L \sim L$

$\theta = 86^\circ \sim 88^\circ$

$\varnothing = 80^\circ \sim 86^\circ$

$s \approx \sqrt{2}\, r + 0{,}5t$

$c = a + t \geq \sqrt{2}\, H$ (where a is as per Figure 1)

R : 3mm ~ 8 mm

Figure B.1 — Example of recommended dimensions of die and punch when using the press brake

B.2 Example of an edge bending tool

An example of tool for the edge bending of test coupons before joining is shown in Figure B.2.

