
**Plastics — Evaluation of the adhesion
interface performance in plastic-metal
assemblies —**

**Part 5:
Fracture energy**

*Plastiques — Évaluation des performances de l'interface d'adhérence
dans les assemblages plastique-métal —*

Partie 5: Énergie de rupture

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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 61, *Plastics*, Subcommittee SC 11, *Products*.

A list of all parts in the ISO 19095 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

There is a growing demand for reliability of metal-plastic joints to make lightweight cars and aircraft, which leads to fuel savings and reduced carbon dioxide emissions. Dissimilar joints of plastics and metals is also an important technology for manufacturing high-performance, low-cost electronic components.

Against this background of industrial trends, new bonding technologies are being developed and test methods for assessing the joint performance of metal-plastic assemblies manufactured in various bonding processes need to be standardized.

ISO 19095-1 through ISO 19095-4 were developed for the metal-plastic assemblies to assess the joint strength, sealing properties and environmental durability.

This document provides a test method to evaluate metal-plastic interfacial fracture energy and to characterize the failure behaviour of joints. This test is therefore useful for qualifying a joint's ability to resist fracture in order to ensure joint integrity.

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Plastics — Evaluation of the adhesion interface performance in plastic-metal assemblies —

Part 5: Fracture energy

SAFETY STATEMENT — Persons using this document should be familiar with normal laboratory practice, if applicable. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices. It is recognized that some of the materials permitted in this document might have a negative environmental impact. As technological advances lead to more acceptable alternatives for such materials, they will be eliminated to the greatest extent possible. At the end of the test, care should be taken to dispose of all waste in an appropriate manner.

1 Scope

This document specifies a method of testing the adhesion in plastic-metal joints produced by several techniques: adhesive bonding, direct joining of thermoplastics by injection or compression moulding, or other methods. More specifically this testing method provides a measure of the joint resistance to fracture in the region between plastic and metal adherends.

This method can only be used for comparing adhesives, surface treatments, bonding conditions and effects of environmental conditions. The results cannot be used for engineering design purposes.

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 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 10365, *Adhesives — Designation of main failure patterns*

ISO 17212, *Structural adhesives — Guidelines for the surface preparation of metals and plastics prior to adhesive bonding*

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 <https://www.electropedia.org/>

**3.1
energy to initiate fracture**

W_F
total input energy needed to bring the test specimen up to fracture initiation

Note 1 to entry: It is expressed in joules, J.

Note 2 to entry: W_F is determined from the load-displacement curve recorded during the test, by integration, as specified in [Clause 6](#).

**3.2
fracture energy**

w_F
energy per unit width of the joining area (e_1)

$$w_F = W_F/e_1$$

Note 1 to entry: It is expressed in joules per metre, J/m.

**3.3
precrack**

non-adhering part of the adjacent faces the two adherends of the joint, acting as a crack initiator

**3.4
precrack length**

a_1
length of the *precrack* ([3.3](#)) in the longitudinal direction of the joint

Note 1 to entry: As specified in [Figure 1](#).

Note 2 to entry: It is expressed in metres, m.

**3.5
'nominal crack' length (before fracture)**

a
distance from the load line (i.e. the line through the centres of the holes for the insertion of the loading pins) to the tip of the *precrack* ([3.3](#))

Note 1 to entry: As specified in [Figure 2](#).

Note 2 to entry: It is expressed in metres, m.

4 Test specimens

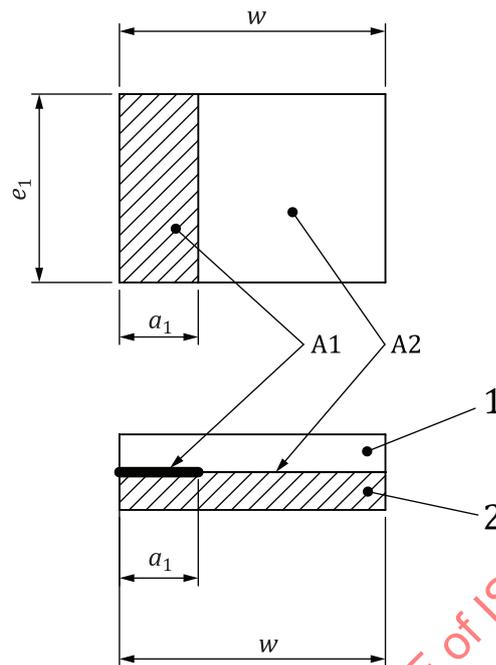
4.1 Shape and size

Test specimens shall be prepared according to [Figure 1](#). Metal and plastic plates having a thickness of $2,0 \text{ mm} \pm 0,1 \text{ mm}$, length w and width e_1 , are joined in such a way as to leave a part of the two plates on one side of the laminate (hatched area in [Figure 1](#), top) not bonded. This part will serve as a precrack, with length a_1 . Specimen dimensions are as specified in [Figure 1](#).

To apply the load to the test specimen, load blocks are tightly bonded to both sides of the plastic-metal laminate in accordance with the geometry as specified in [Figure 2](#).

The length, a , of the 'nominal crack' should preferably be in the range $0,45 < a/W < 0,55$, and the specimen width, e_1 , is preferably equal to $W/2$.

Dimensions in millimetres



e_1	w	a_1
$12,5 \pm 0,2$	$17,5 \pm 0,2$	$5,0 \pm 0,1$

Key

- a_1 precrack length
- e_1 width of the joining area
- w length of the metal and plastic plates
- 1 metal plate $2,0 \text{ mm} \pm 0,1 \text{ mm}$ thick
- 2 plastic plate $2,0 \text{ mm} \pm 0,1 \text{ mm}$ thick
- A1 precracked part
- A2 joining part

Figure 1 — Test specimen for interfacial fracture energy measurement

4.2 Procedure for test specimen preparation

Before bonding, the surfaces involved in bonding are degreased and carefully inspected to exclude possible contamination. In the case of anisotropic materials, the reference direction shall be marked on each adherend.

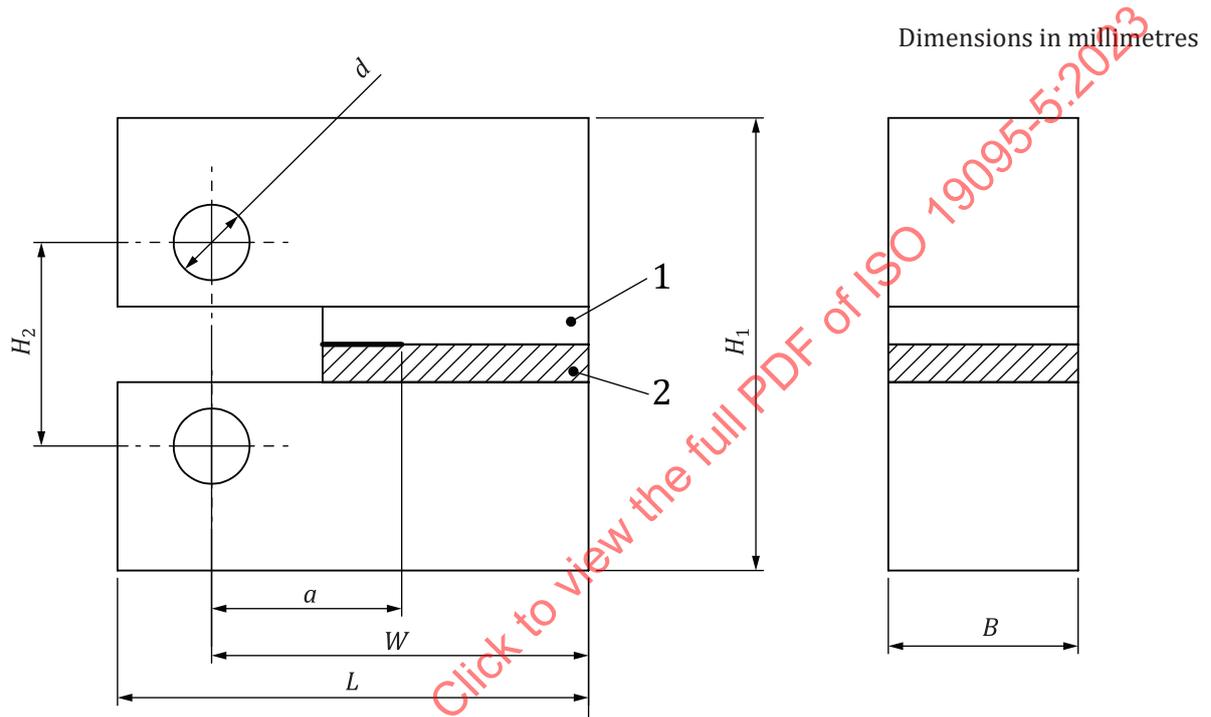
The precrack part (A1 in [Figure 1](#)) is prepared either by coating with non-stick ink the defined surface of the metal adherend (see [Figure 3](#)), or by inserting a piece of non-stick film, which is recommended to be PTFE with a thickness between $50 \text{ }\mu\text{m}$ and $100 \text{ }\mu\text{m}$, between the metal and the plastic plates.

The metal and plastic plates are bonded either by adhesive, or directly by injection moulding-or compression moulding, or by other methods.

In the case of adhesive bonding, the thickness of the adhesive layer shall be carefully controlled and shall be less than 1 mm. The thickness of the layer shall not vary by more than 20 % within one joint, and the average thickness of the layer in one joint shall not differ by more than 20 % from that in another joint in the sample. When the adhesive is fully consolidated, remove any excess adhesive by mechanical means carefully enough not to weaken the bond, so as to leave the joint with smooth sides. The average thickness of the consolidated adhesive layer shall be determined for each specimen

by measuring the total thickness of the bonded laminate and subtracting the thicknesses of the two adherends. The value of the layer thickness shall be selected by the user, based upon the adhesive manufacturer's recommendations or in consideration of the intended application. It is beyond the scope of this document to specify full manufacturing details of the joints to be tested. Such information should be sought from the adhesive manufacturer and/or the substrate manufacturer.

The test specimen thus prepared shall be tightly bonded to the load blocks made of metal using a suitable adhesive, as specified in Figure 2. The material of the load blocks is recommended to be an aluminium alloy or stainless steel. The adhesive can be of any type as long as it has sufficient stiffness and strength not to fail during the test. The preparation of the test specimens shall be in accordance with ISO 17212.



Dimensions in millimetres

L	H_1	H_2	W	B	a	d
$31 \pm 0,2$	$30 \pm 0,2$	$13,5 \pm 0,2$	$25 \pm 0,2$	$12,5 \pm 0,2$	$12,5 \pm 0,1$	$5 \pm 0,1$

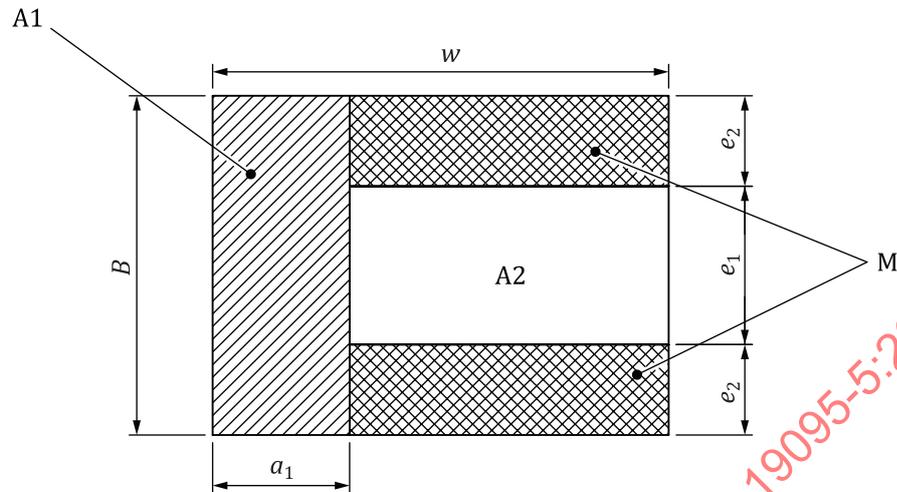
Key

- L overall width of the loading blocks
- W distance between the loading line (line through the centres of the holes for the loading pins) and the back edge of the laminate
- H_1 overall height
- H_2 distance between centres of the two pin holes in the loading blocks, symmetrically located with respect to the crack plane
- d diameter of the pin hole
- B width of the adherends and of the loading blocks
- a 'nominal crack' length (before fracture)
- 1 metal plate $2,0 \text{ mm} \pm 0,1 \text{ mm}$ thickness
- 2 plastic plate $2,0 \text{ mm} \pm 0,1 \text{ mm}$ thickness

Figure 2 — Arrangement of the test specimen between the loading blocks

If the test specimen detaches from the loading blocks before it fractures in the plastic-metal bonding region, the test is invalid. In an attempt to avoid this, the joining area may be reduced up to 50 % of the

original joining area (as specified in [Figure 1](#)) by masking the surface of the substrate as indicated in [Figure 3](#). The width of the masked area, e_2 , is less than $B/4$.



Key

- B width of the adherends (metal or plastic plate): $e_1 + 2e_2 = B$
- e_1 width of the joining area, with the condition: $e_1 \geq \frac{B}{4}$
- e_2 total width of the mask area, with the condition: $e_2 \leq \frac{B}{4}$
- A1 precrack part
- A2 joining part
- M masked part

Figure 3 — Masking of part of the adherends surface to reduce joint strength

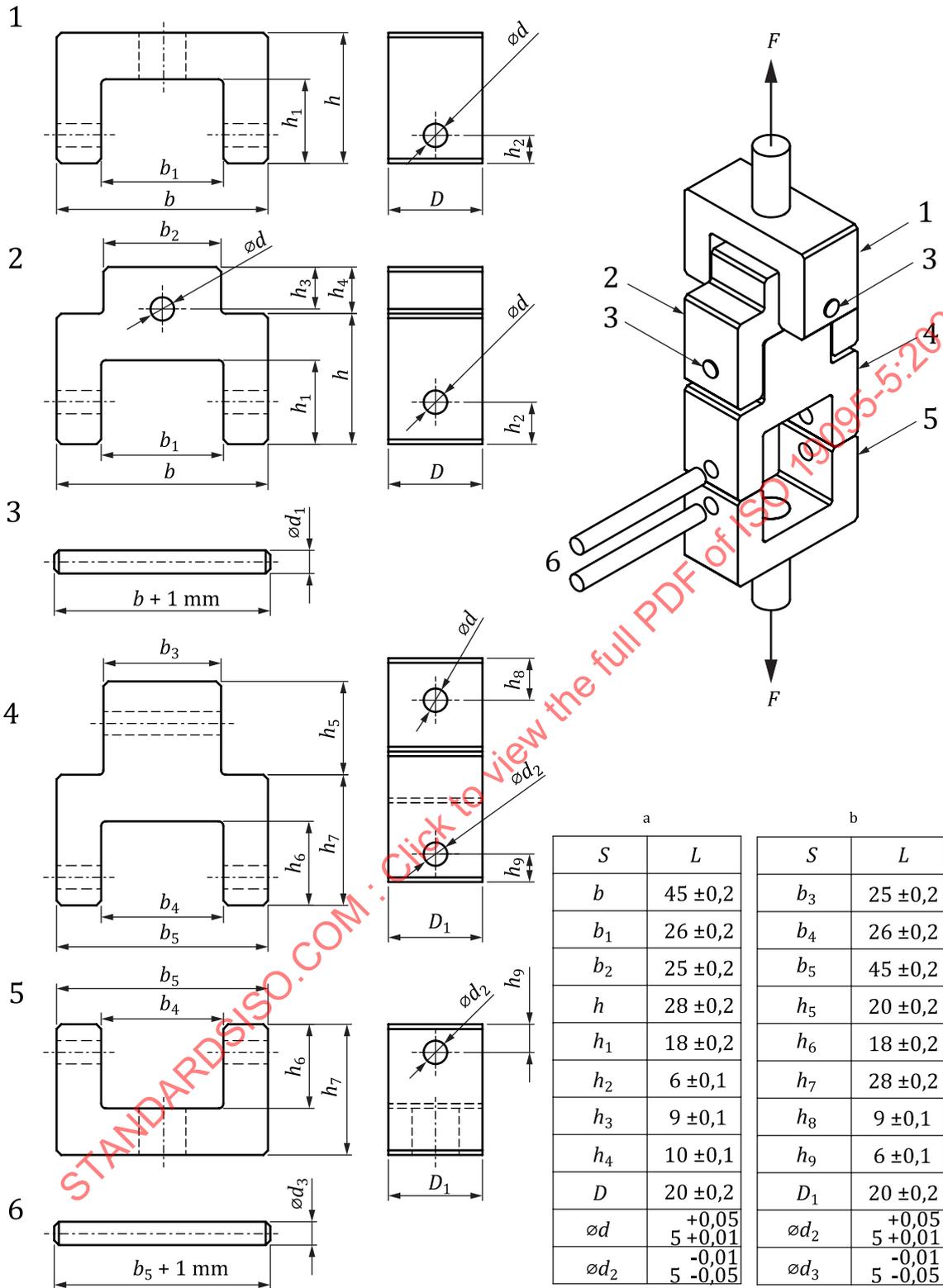
5 Test procedure

5.1 Test machine

The test machine shall satisfy the requirements of ISO 5893. The load indicator shall show the total load carried by the test specimen. This device shall be essentially free from inertia lag at the test speeds used. It shall indicate the load with an accuracy of at least 1 % of the actual value.

5.2 Loading rigs

The test specimen is loaded by connecting the jaws of the tensile tester to the load blocks that hold the specimen via two pins inserted into the holes in the load blocks. The displacement of the load points during the test is measured near the pins (see [5.3](#)). An example of a loading clevis designed for this test is shown in [Figure 4](#).



Key
S symbol
L length

Figure 4 — Clevis designed for interfacial fracture energy measurements

5.3 Displacement measurement

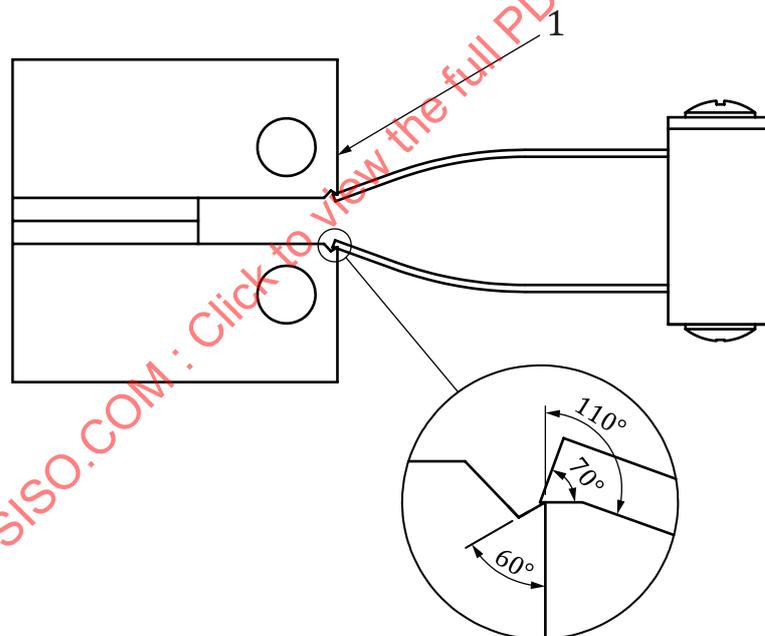
An accurate displacement measurement is required to determine fracture energy accurately. The displacement is recorded during the test. The transducer shall be essentially free from inertia lag at the test speeds used. It shall measure the displacement with an accuracy of 1 % of the relevant length or better. The effects of the transducer on load measurements should also be negligible (that is <1 %). A compensation for machine compliance shall be installed and used in a way that the required accuracy class will be achieved under load (see ISO 9513).

The displacement measurement shall be performed using the machine's stroke (position) transducer. If the machine's stroke transducer has insufficient precision, then an externally applied displacement-measuring device shall be used. The device shall be mounted across the loading pins to measure the displacement at the load point.

Exact positioning of the gage on the specimen is essential, yet the gage shall be released without damage when the specimen breaks. Displacement gage and knife-edge designs shall provide for free rotation of the points of contact between the gage and the specimen. A recommended design for a self-supporting, releasable displacement gage is given in [Figure 5](#).

The specimen shall be provided with a pair of accurately-machined knife edges on the metal blocks to support the gage arms. The knife edges may be machined in the metal blocks as suggested in [Figure 5](#).

It is not the intent of this test method to exclude the use of other types of gages or gage-fixing devices.



Key

- 1 optional integral-machined knife edge

Figure 5 — Example of displacement-measuring device, double-cantilever clip-in displacement gauge showing mounting by means of knife edges of the metal block

5.4 Measurements of test specimen dimensions

All dimensions of the joint under test (that is of the test specimen) including its 'nominal crack' length but excluding the dimensions of the loading blocks and the clevis shall be reported in the test report (see [Clause 9](#)).

Readings of the precrack length, a_1 , shall be taken at 5 points along the front of the precrack: at the edges, in the centre and halfway between the centre and the edges. To make these readings possible,

the joint must be broken open so that the front line of the precrack is visible. These measurements can therefore only be performed after completion of the test. Care should be taken that it is the original precrack tip that is observed since slow crack growth may have occurred during the test. The precrack length shall differ by no more than 10 % over the entire precrack front. The average of five (5) valid readings shall be reported in the test report [item d) in [Clause 9](#)].

5.5 Conditioning

The test specimen shall be conditioned as specified in the appropriate standard for the material concerned. In the absence of this information, the most appropriate set of conditions from ISO 291 shall be selected and the conditioning time is at least 16 h, unless otherwise agreed upon by the interested parties, for example, for testing at elevated or low temperatures.

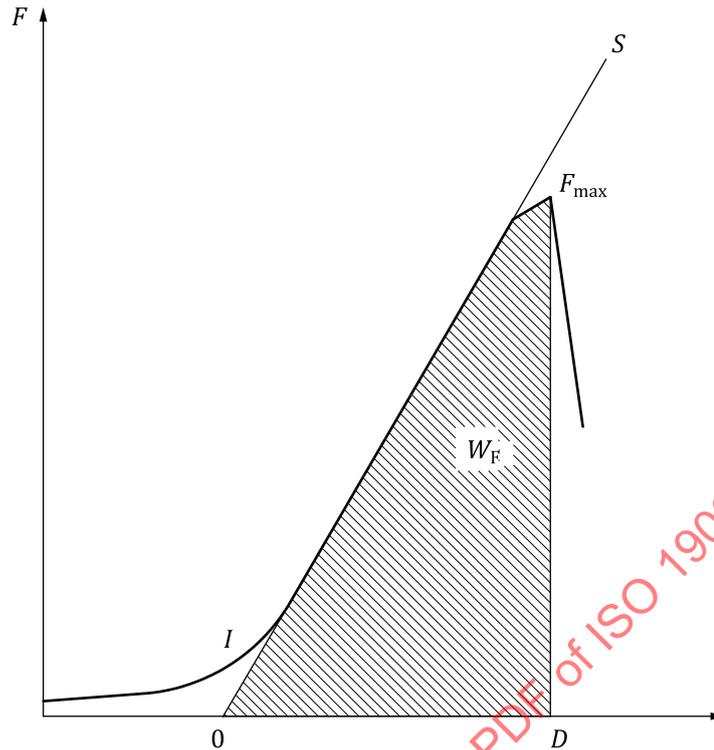
5.6 Test procedure

There is a moment in time when the load measurement shall be put to zero, there is a given moment in the sequence when the strain measurement shall be put to zero (see ISO 527-1). It is recommended that 23 °C and a test speed of 10 mm/min to be used as the basic test conditions. In all cases, the loading time and the environmental temperature shall be measured. Speeds greater than 0,1 m/s and loading times less than 10 ms should preferably be avoided since dynamic effects may cause errors. Carry out at least five tests for each set of conditions.

6 Evaluation of the fracture energy

The energy to initiate fracture W_F is calculated from the load-displacement curve as shown in [Figure 6](#). In most cases, there is some non-linearity in the curve and this can be mainly due to machine compliance (in the initial part of the curve) and plastic deformation at the crack tip (just before fracture initiation). The line OS is drawn, in such cases, to the load-displacement curve with the slope of the initial linear portion of the diagram. The area under the curve from the point (0) where the line and the displacement axis intersect to the point at which the first abrupt drop of the load occurs (F_{max}) is calculated. The latter point is conventionally assumed to represent fracture initiation.

Calculate the fracture energy w_F as the energy to initiate fracture W_F divided by the width of the joining area e_1 .

**Key**

- F force
 I initial nonlinearity
 D displacement

Figure 6 — Typical type of load-displacement curve and definition of energy to initiate fracture (W_F)

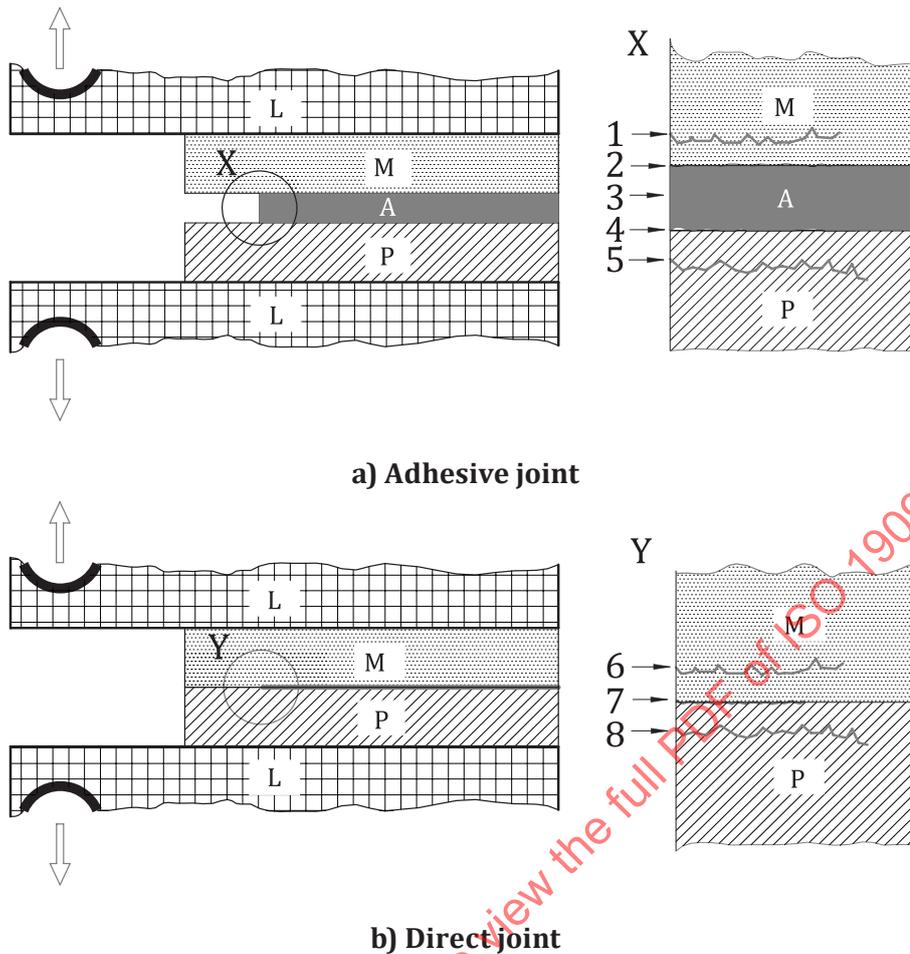
7 Failure pattern and test validation

Metal-plastic joints can be classified into two main types: (a) adhesive joints and (b) direct joints. Their failure patterns, in accordance with ISO 10365, can be classified into the types shown in [Figure 7](#).

In adhesive joints (type a), the failure can occur at either of the two interfaces metal/adhesive (Key 2) or plastic/adhesive (Key 4), or within the adhesive layer (Key 3), or within either of the two adherends, metal (Key 1) or plastic (Key 5).

In direct joints (type b) the failure can occur at the metal/plastic interface (Key 7) or inside the metal (Key 6) or the plastic (Key 8).

In Keys 2, 4 and 7 failure is designated as interfacial or “adhesive failure”; in Keys 1, 3, 5, 6 and 8, failure is designated as “cohesive failure”.



Key

- | | |
|---|--|
| 1 cohesive failure in metal | 7 interfacial failure at metal/plastic interface |
| 2 interfacial failure at metal/adhesive interface | 8 cohesive failure in plastic |
| 3 cohesive failure in adhesive layer | L loading block |
| 4 interfacial failure at adhesive/plastic interface | M metal |
| 5 cohesive failure in plastic | A adhesive |
| 6 cohesive failure in metal | P plastic |

Figure 7 — Loci of failures in adhesive joint and direct joint

The latter cases are outside the scope of this test procedure. Consequently, in these cases the test shall be considered INVALID and the measured value of w_F shall be rejected as it does not comply with the requirements set out in this test procedure.

Mixed modes of failure can also occur, where the failure is partly “adhesive” and partly “cohesive” along the crack front or along the path of the advancing crack or both. These cases are also outside the scope of this test procedure and therefore the test must be considered INVALID and the measured value of w_F shall be rejected.

The type of failure pattern that has occurred shall be assessed by visual inspection of the fracture surface on the two parts of the broken joint, after the test. Since the test aims to characterize the resistance of the joint to fracture at initiation, only the features of the initial portion of the fracture surface extending 2 mm beyond the tip of the precrack (corresponding to a crack growth of 2 mm) shall be considered to assess the validity of the test.